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ABSTRACT

Phase II of a project extended data collection and analytic procedures to develop a model of expertise and skill development for en route air traffic control (ATC). New data were collected by recording the Dynamic Simulator (DYSIM) performance of five experts with a work overload problem. Expert controllers were interviewed in depth for mental model elaboration and validation. Federal Aviation Administration data regarding operational errors were analyzed. An extended literature review was conducted to integrate findings with existing literature. An elaborated and refined mental model and task decomposition were developed. The structure of the mental model implied both a conceptual framework used by the controller for organizing ATC knowledge and a strategy for applying the knowledge in job conduct. The task decomposition resulted in a listing and validation of 12 tasks. The analysis of strategy usage showed that experts tended to use fewer strategies, a greater variety of different strategies, more workload management strategies, and strategy usage that varied with context. A working model of interrelationships among key ATC constructs was developed. A revised listing of critical cues of work overload indicated that participants viewed anxiety and communication errors as being the most important cues that an overload situation was developing. Training implications were identified in the areas of instructional content, sequencing, media delivery, and training environment. (Appendixes include the following: a list of 57 references, a glossary of terms and acronyms, a glossary of strategies, a validation study timeline, strategy listings and validation interviews, retrospective protocols of DYSIM overload problem solving, a work overload questionnaire, and an error listing for DYSIM overload problem solving.) (YLB)

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COGNITIVE TASK ANALYSIS OF EN ROUTE AIR TRAFFIC CONTROL: MODEL EXTENSION AND VALIDATION

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Abstract

A cognitive task analysis was performed to analyze the key cognitive components of the en route air traffic controllers' job.

Our goal was to ascertain expert mental models and decision-making strategies, and to identify important differences in controller knowledge, skills, and mental models as a function of expertise. By comparing experts, intermediates, and novices, the cognitive analysis provides a much better understanding of skill progression than would traditional, behavioral methods of task analysis. This understanding can serve as a foundation for improving the training of professional air traffic controllers, and provides important insights into improved training methods for other complex, high-performance job environments that require speedy decision-making and prioritization of competing tasks (such as aircraft flight decks, nuclear power plant operation, and combat information centers).

This report presents the results from the model extension and validation phase of the task analysis. The first phase of the cognitive task analysis had included the development of an expert mental model of air traffic control and associated tasks and strategies. The Phase II findings reported herein extend and validate the model and expert strategies. Phase II analyzed the critical cues of work overload and operational error data, and the original data were subjected to further analysis. New work overload data were also collected and analyzed. This iterative process of data collection led from the analysis of general controller expertise to a narrower analysis of controller expertise under conditions of heavy workload.

This report also provides an integration of the findings and training recommendations from Phases I and II of the analysis, resulting in a comprehensive view of controller expertise and an integrated model for training development for the Federal Aviation Administration's new en route air traffic control curriculum.

This research represents one of the first uses of cognitive task analysis to support the development of a complete curriculum for the training of a complex, high-performance task. The results suggest exciting and innovative approaches for air traffic control training, as well as for training other tasks that must be performed in a time-constrained, multi-tasking environment.

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I. INTRODUCTION

I. INTRODUCTION

Purpose

The Cognitive Task Analysis of Prioritization in Air Traffic Control (see Human Technology, 1990) presented initial findings concerning the cognitive aspects of the job of en route air traffic controller. A preliminary mental model was developed, and major tasks, task triggers, and task subgoals were specified. In addition, controller strategies, goals, and methods were delineated.

Because the findings of this cognitive task analysis work have important implications for the redesign of en route controller training, it is important to extend and validate these findings before incorporating their implications into the curriculum redesign blueprint. This current report describes the results of the extension and validation effort.

The overall goal of this analysis project was to extend the data collection and analytic procedures used previously to permit further development of a model of expertise and skill development for en route air traffic control. The subgoals of the analysis were:

- To further specify and validate:
  - Mental model categories and contents
  - Tasks, task triggers, and task subgoals
  - Expert-typical strategies in relation to the tasks and mental model
  - Critical cues of work overload and associated workload-reduction aids
- To develop a model of skill development as related to:
  - Strategy selection

As with all the front-end-analysis activities, the focus of this analysis was on the development of practical information that will be directly applicable to the en route curriculum redesign process.

General Approach

The general approach to the cognitive analysis of en route air traffic control (ATC) has been described previously (see Human Technology, 1990). The overall framework is a modification of the integrated task-analysis methodology developed by Ryder and Redding (1990). This current project entailed an extension of the Stage 2: Refinement and Learning Analysis conducted previously.

General Approach (Continued)

The model of controller expertise was refined to a greater level of specificity and validated, while a learning analysis was conducted to determine how strategy selection differs as a function of level of expertise. The latter analysis permitted examination of the process of skill development. Derivation of a novice-to-expert skill progression is valuable for identifying knowledge and skill areas that separate expert from novice performance, and for determining instructional sequencing.

The data collected previously were analyzed further, and new data were collected by recording the Dynamic Simulator (DYSIM)* performance of five experts with a Work Overload Problem. In addition, expert controllers were interviewed in depth for mental model elaboration and validation. Federal Aviation Administration (FAA) data regarding operational errors were analyzed. Finally, an extended literature review was conducted to integrate the findings of this study with existing literature.

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*NOTE: Technically, the FAA Academy simulator is a VAX-based stand-alone simulator rather than a Dynamic Simulator (DYSIM), but DYSIM is used throughout this report to emphasize that data were collected from simulated situations.

II. MENTAL MODEL AND TASK DECOMPOSITION

II. MENTAL MODEL AND TASK DECOMPOSITION

Method

Participants

The participants were as follows:

Original Data Collection. Participants included five supervisory air traffic control specialists (see Human Technology, 1990).

Model Extension. Participants included two current Full Performance Level controllers (FPL's).

Model Validation. Participants included two FAA Academy instructors.

Procedures

The procedures used are described below.

Original Data Collection. Data were obtained from the DYSIM performance of five participants on four different problem scenarios (two 65% complexity and two 100% complexity problems). Individual DYSIM performance on each problem was videotaped as the participants worked uninterrupted. In a subsequent session, each problem was replayed with each participant and a verbal protocol was obtained to determine why the participants did each group of actions, what their goals were, how they were making decisions, toward what goals the actions were targeted, etc. (see Human Technology, 1990, pp.12-13 for details). Based on this analysis, a preliminary mental model and a task decomposition were constructed using the COGNET (Cognitive Network of Tasks) methodology (see Zachary et al., in press).

Model Extension. Refinement of the preliminary model was based on the original DYSIM performance modeling data collected during the first phase of the project. The 20 original protocols were reanalyzed for the following reasons:

- To obtain greater detail in task subgoals, task triggers, and mental model contents.
- To yield consistency in level of analysis and terminology among tasks and between the tasks and the mental model.
- To obtain a better understanding of the cognitive aspects of each task.

Procedures (Continued)

Model Extension (Continued)

Two expert FPL's viewed a subset of the videotapes of the original DYSIM problems, critiqued them, and answered questions about alternative methods for handling the same problems and about general methods and strategies for handling a sector. Additional input was provided by observation of a variety of controllers handling different types of sectors in one ARTCC (Air Route Traffic Control Center), as well as review of the results of the other first phase analysis efforts.

The mental model and the task decomposition were completely revised taking into account all of the above input, while relying most heavily on the data reanalysis. The two FPL's who had assisted in the reanalysis then evaluated the revised model to ensure the accuracy of the interpretations.

Validation Methodology. The goal of the validation study was to demonstrate that the mental model and the task decomposition provide a useful framework for describing an individual controller's performance. Additionally, the validation effort also provided further data for refinement of the model. This process is consistent with the iterative model-building approach described in Ryder and Redding (1990).

The validation study assessed the construct validity of the mental model and the task decomposition (i.e., the extent to which the model actually reflects controller mental models and knowledge) of the expert model of en route air traffic control. The following questions were asked:

1. Do the participants describe their cognitive processes in terms of the panels and levels of the mental model (i.e., does the mental model structure accurately represent an expert-typical problem representation)?
2. Do the task triggers accurately indicate the conditions for task initiation?
3. What changes in the problem situation trigger attention shifts from one task to another?
4. Can the participants' actions (both behavioral and cognitive) be accounted for completely by the 12 tasks contained in the task decomposition?

The validation of the mental model and task decomposition was based on data collected from a DYSIM Work Overload problem performed by two experienced FPL's. First, the controller worked through the entire scenario without interruption. Immediately following the problem session, the scenario was played back. During the playback, the controller was queried about the progression of events and controller actions in relation to scenario events, including the controller's thought processes.

Measures And Data Analysis

The data analysis procedures and measures used were as follows:

Original Data Collection. The task decomposition was developed by first analyzing the videotaped DYSIM problems and protocols to determine segments of related activity. Each segment of related activity was indicated on a timeline for each of the problems. This analysis resulted in a preliminary list of tasks and the observable activity associated with each task. Following this, comparisons were made across participants and problems to determine what the major tasks were. The specific tasks identified in each participant's timeline protocol were then compared, and the task lists were compiled across subjects and correlated for commonality. After this was done for all timelines, tasks were grouped into similar areas and assessed on dimensions of:

> "Is task A a part of task B (or vice versa)?"
>
> "Are tasks A and B both instances of some more abstract task C?"

As a result of this process, a preliminary task decomposition was defined.

Initial derivation of the mental model involved an analytical process of determining how the individual controller thinks about controlling a sector. The model was derived from a global understanding of the Air Traffic Control (ATC) job obtained from: viewing the videotaped problems in conjunction with the protocols of what and how each controller was thinking about his problems, reading ATC documentation and procedural manuals (FAA 7110.65), and interviewing subject-matter experts (SME's). The organization of the mental model into panels involves a breakdown of the domain (i.e., the subject matter of ATC) into logical partitions of knowledge, based both on characteristics of the information and on how it is used in task performance. The further breakdown of panels into levels involves determining how expert controllers categorize the type of information in that panel.

Model Extension. The model development was essentially an iterative process of refinement, in which each iteration provides greater detail and the corrections of model components based on formerly incomplete understandings (see Ryder & Redding, 1990). The observable aspects of the model (behavioral) can be determined in early iterations because they are explicit in the videotapes of controller actions. The cognitive aspects of the model must be added in subsequent iterations, because they must be derived from the protocols and inferred from interviews with SME's. It is difficult to break this process into sequential steps, because each aspect of the model develops in a progressive fashion as knowledge and understanding of the domain increase.

Measures And Data Analysis (Continued)

Model Extension (Continued)

The mental model development thus followed a pattern of scientific theory development, in which a preliminary structure is developed and each new bit of knowledge is fitted into that structure until there is some phenomenon that cannot be handled by the current structure. When that happens, a new structure is developed that handles the old and new knowledge. This process of refinement continues until a sufficient number of new examples of sector control can all be understood within the mental model structure. At the end of the initial data collection and analysis phase, a preliminary mental model structure and contents had been formulated. Subsequent mental model refinement resulted from increased knowledge of the domain and from integration with the tasks. During model extension, the specific contents ("Messages") of each level within each panel were specified in greater detail.

Development of the task decomposition also built on the preliminary one developed in the first project phase. The task subgoals within each task were reviewed for errors of omission and commission, as well as ordering within the task. In addition, some subgoals were decomposed to lower levels. As part of this extension process, it became clear that some tasks that were originally considered independent tasks should really be subgoals of other tasks, resulting in a revision of the original task decomposition. Specific motor and cognitive operations (i.e., sub-subgoals or discrete actions) required for the tasks are not included, because this level of analysis has been handled elsewhere (i.e., the behavioral task analysis conducted by CTA (Ammerman et al., 1987-revised 1990)). A second aspect of the task decomposition extension/refinement involved incorporating more cognitive aspects of ATC that had not been apparent in the preliminary analysis. Third, the task triggers were analyzed in greater detail resulting in additional triggers and specification of the triggers in terms of patterns of information in the mental model. This analysis was done in conjunction with the mental model revisions to ensure compatibility between the tasks and the mental model.

Finally, perceptual events were also delineated. Perceptual events are situational changes that occur unrelated to the performance of a task (for example, a request from a pilot). Unlike the 12 tasks, their conditions/triggers are not based on the current contents of the mental model, but instead are based upon workstation-based information, such as a new data block appearing on the PVD (Plan View Display). Once this information is added to the mental model, however, it may affect the flow of attention because task triggers are based upon patterns of information in the mental model. Perceptual events consist of a trigger based on a change in the situation in the sector, and methods for adding that information to the appropriate place in the mental model.

Validation. Analysis involved constructing a timeline of the problem, which included controller actions (from the videotaped problems), situational changes, and controller thought processes (the latter derived from the protocols). The timelines were used to determine when the individual was performing each task, what triggered the task, the relevant information in the mental model pertaining to the task, and the controller operations involved in that task.

Measures And Data Analysis (Continued)

Validation (Continued)

The data collected from one of the experts were used to construct the timeline (see Appendix A). The validation effort collected data from two participants, but an examination of the data did not reveal significant differences between them. Because the focus was upon demonstrating that the model accurately described controller thought and actions, rather than testing its predictive validity (i.e., the extent to which it can predict actual job behavior), analysts felt that two participants were sufficient for the validation.

A detailed analysis of these data is presented in a timeline of 46 selected task events (a task event is an instance of a task) from the 30-minute scenario and subsequent playback session. The timeline contains data from the initial DYSIM session and the subsequent playback session, specifically:

Time: The approximate time in the 30-minute scenario that marks the beginning of the task event.

Current Task Event: The task that is currently being performed.

Triggers To Task: The trigger(s) that cause the controller to perform the current task.

Relevant Information From Mental Model: The information used during the execution of the current task. This information would be contained in messages in the pertinent panels and levels in the mental model.

Pertinent Mental Model Panel And Levels: The specific panels and levels that would contain the above information.

Controller Thoughts And Actions: Steps such as cognitive assessment, controller actions, and plans related to the task event. Evidence for cognitive operations (i.e., "thought") are drawn from statements made by the participant in the subsequent playback session. Controller actions are drawn from the raw performance data.

Results

Results: Mental Model

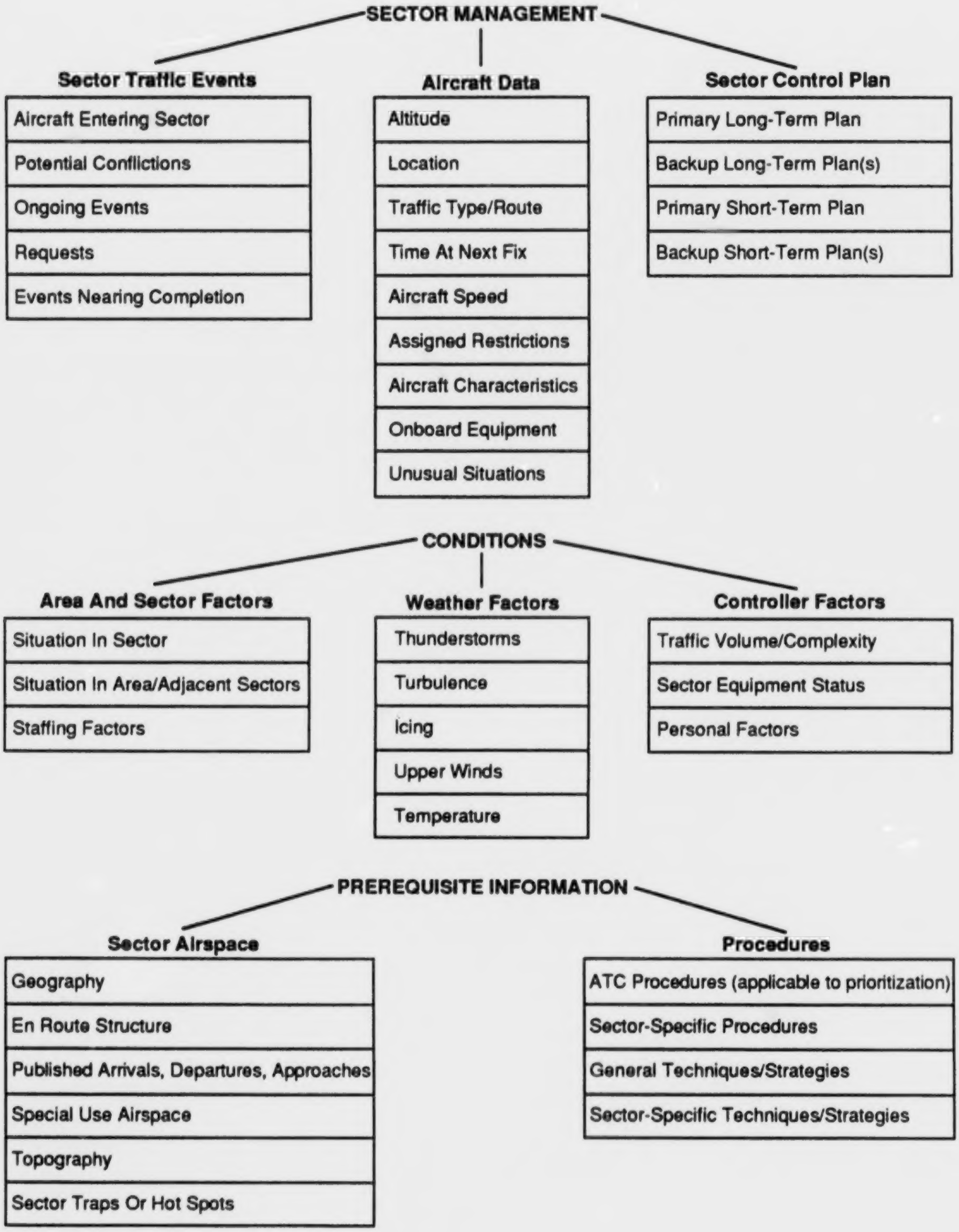
The mental model of en route air traffic control is the representation of the knowledge a controller has of an evolving sector situation. Its structure implies a conceptual framework used by the expert controller for organizing ATC knowledge and implies a strategy for applying that knowledge in job conduct. This model depicts the categories of knowledge (depicted as mental model categories, panels, and levels) required to support performance of the 12 tasks described in the next section. It serves as an "organizer" of information: a "mental checklist" of factors the controller should consider as part of his/her decisionmaking (depicted as levels of each panel), as well as the relative importance of each set of factors (from the ordering of levels within a panel). The mental model's contents at any particular time represent the controller's situational awareness.

The mental model is shown in Figure 1. It contains three categories (Sector Management, Conditions, and Prerequisite Information). Each category contains either two or three panels, and each panel is divided into levels. The Sector Management and Conditions categories contain information relating to the situation in a specific sector at a particular time, while the Prerequisite Information category contains knowledge of the sector and air traffic control procedures, strategies, and techniques that should have been learned (and committed to long-term memory) prior to a controller taking over a sector. The Sector Management category can be thought of as the dynamic knowledge of the sector situation. The Conditions category contains factors that influence general workload and selection of specific strategies for handling events. Thus, the first two categories are relatively dynamic. The Prerequisite Information category, on the other hand, is relatively stable.

Figure 2 depicts the salient functional characteristics of the various categories and panels within the mental model. The definitions of the categories and their panels, along with the basic rationale for this organization, are described next.

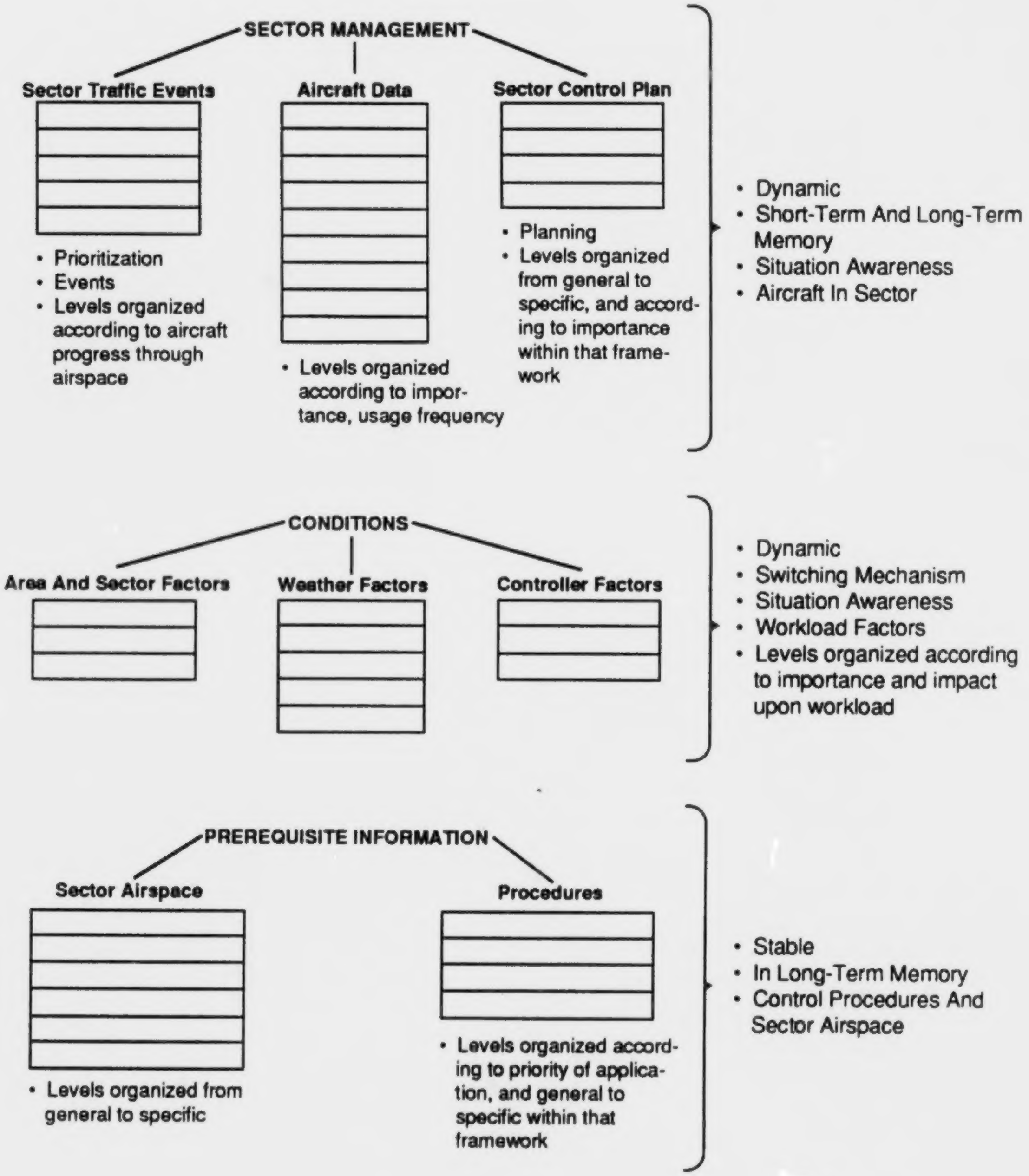
Results: Mental Model (Continued)

Figure 1. Expert Mental Model Of ATC


SECTOR MANAGEMENT
Sector Traffic Events
Aircraft Entering Sector
Potential Conflictions
Ongoing Events
Requests
Events Nearing Completion
Aircraft Data
Altitude
Location
Traffic Type/Route
Time At Next Fix
Aircraft Speed
Assigned Restrictions
Aircraft Characteristics
Onboard Equipment
Unusual Situations
Sector Control Plan
Primary Long-Term Plan
Backup Long-Term Plan(s)
Primary Short-Term Plan
Backup Short-Term Plan(s)
CONDITIONS
Area And Sector Factors
Situation In Sector
Situation In Area/Adjacent Sectors
Staffing Factors
Weather Factors
Thunderstorms
Turbulence
Icing
Upper Winds
Temperature
Controller Factors
Traffic Volume/Complexity
Sector Equipment Status
Personal Factors
PREREQUISITE INFORMATION
Sector Airspace
Geography
En Route Structure
Published Arrivals, Departures, Approaches
Special Use Airspace
Topography
Sector Traps Or Hot Spots
Procedures
ATC Procedures (applicable to prioritization)
Sector-Specific Procedures
General Techniques/Strategies
Sector-Specific Techniques/Strategies

Results: Mental Model (Continued)

Figure 2. Characteristics Of Mental Model Categories And Panels


SECTOR MANAGEMENT
Sector Traffic Events
Aircraft Data
Sector Control Plan
• Prioritization
• Events
• Levels organized according to aircraft progress through airspace
• Levels organized according to importance, usage frequency
• Planning
• Levels organized from general to specific, and according to importance within that framework
• Dynamic
• Short-Term And Long-Term Memory
• Situation Awareness
• Aircraft In Sector
CONDITIONS
Area And Sector Factors
Weather Factors
Controller Factors
• Dynamic
• Switching Mechanism
• Situation Awareness
• Workload Factors
• Levels organized according to importance and impact upon workload
PREREQUISITE INFORMATION
Sector Airspace
Procedures
• Levels organized from general to specific
• Levels organized according to priority of application, and general to specific within that framework
• Stable
• In Long-Term Memory
• Control Procedures And Sector Airspace

Mental Model Category: 1) Sector Management

In general, the Sector Management panels contain information about the aircraft approaching or in the sector, the events of which these aircraft are a part, and the control plan and actions that the controller is planning to use to separate these aircraft. The three panels in this category are:

- **Sector Traffic Events**—This panel contains an understanding of the events that are occurring or are anticipated to occur in the sector. The elements of this panel are events involving one or more aircraft.
- **Aircraft Data**—This panel contains basic data about each aircraft in the sector. Information on this panel is used in reasoning about the current situation and in categorizing aircraft into events (i.e., arrivals) on the Sector Traffic Events panel.
- **Sector Control Plan**—This panel contains primary and backup, long-term and short-term plans for dealing with current and future events.

The Sector Traffic Events panel is the primary panel used in prioritization of decisionmaking, because it represents the understanding of the events that must be considered. However, determining how to deal with each event necessarily involves reference to the data on the Aircraft Data panel and the three Conditions category panels, and other events on the Sector Traffic Events panel, as well as knowledge of standard and sector-specific procedures and strategies from the Procedures panel. The events are also interpreted with reference to the static spatial representation of the sector airspace (embodied on the Sector Airspace panel).

The organization of the Sector Management category implies a specific decisionmaking flow, as follows. The controller perceives data from the PVD, from the flight progress strips, and from communication with pilots about individual aircraft. The controller then processes these data about individual aircraft and categorizes them into events that must be handled (as part of the Maintain Situation Awareness task). An event is a high-level construct that represents an important control situation involving one or more aircraft. The long-term plan for controlling the sector is devised to handle events (represented as the Primary and Backup Long-Term Plan levels) and then is translated into a detailed plan of specific control actions involving individual aircraft (represented as the Primary And Backup Short-Term Plan levels).

As described above, decisionmaking involves events rather than individual aircraft. By learning procedures and strategies for event types, the amount of information that must be remembered at any one time is significantly less than if all data about each aircraft had to be actively considered to make decisions. This representation is also consistent with: the findings of the strategy analysis that experts tend to include more aircraft within a single control action; the key finding of an earlier study that expert controllers group aircraft into event patterns according to the type of control problem they present (Schlager, Means, & Roth, 1990); and the theoretical perspectives of other investigators (e.g., Cushing, 1989; Langen-Fox & Empson, 1985). There are also some data suggesting that less-experienced controllers may deal with aircraft on an individual basis (Harwood, Roske-Hofstrand, & Murphy, 1991).

Mental Model Category: 1) Sector Management (Continued)

The dynamic aspects of the mental model, including event types, are assumed to be either in working memory or easily accessible from long-term memory. The capacity of working memory is not large enough for even the complete Sector Management category contents to be in working memory at one time (Sarter & Woods, 1991). However, the critical events, their status, some relevant data on the aircraft involved, and the plan for dealing with the critical events most likely will be in working memory.

Experts will, of course, have larger chunks of information, resulting in a greater effective working memory capacity. Chunking appears to distinguish experts from novices (Chase & Simon, 1973; Egan & Schwartz, 1979). Expert chess players, for example, are better able to encode and recall the location of chess pieces on the board because they have the expertise to know how to group several pieces into related clusters (i.e., "chunks") according to the important patterns and events on the gameboard (deGroot, 1965). Similarly, expertise in ATC partly involves perceiving and categorizing individual aircraft into related clusters based on the important events unfolding in the sector. Practice in thinking about ATC in terms of events should enhance organization and recall of individual aircraft for all levels of controllers, particularly novices. Because the capacity of human short-term memory is limited to between 5 and 9 "chunks" (events, in our framework) of information, "we can increase the number of bits of information that it contains simply by building larger and larger chunks, each chunk containing more information than before" (Miller, 1956, p. 93).

Mental Model Category: 2) Conditions

The Conditions panels include conditions or factors that change a controller's "usual" strategy, resulting in a potential increase in actual or perceived workload. The three panels in this category are:

- **Area And Sector Factors** —This panel contains factors that affect the controller's strategy and workload.
- **Weather Factors**—This panel contains weather factors that affect controller strategy or aircraft performance and thus contribute to increases in cognitive workload.
- **Controller Factors**—This panel contains factors specific to the individual controller that determine the controller's general level of stress and workload.

Mental Model Category: 3) Prerequisite Information

Taken together, the Prerequisite Information panels contain the knowledge of the "physical" structure of the sector and the procedures by which control is carried out. The two panels in this category are:

- **Sector Airspace**—This panel contains knowledge about the spatial layout of the sector and its characteristics.

Mental Model Category: 3) Prerequisite Information (Continued)

- **Procedures**—This panel contains knowledge about the general procedures for separating aircraft and strategies for handling different kinds of situations.

The Prerequisite Information category includes both general ATC information and information relevant to a specific sector. General ATC information is contained in the Procedures panel within two levels: ATC Procedures and General Techniques/Strategies. The other portions of the category contain sector-specific information. Obviously, a controller moving from one area to another would need to learn new sector-specific information as indicated by these portions of the mental model.

Mental Model: Levels Within Category Panels

The panels of the mental model consist of various levels that have been grouped together because of their functional characteristics. For instance, the levels labeled Thunderstorms, Turbulence, Icing, Upper Winds, and Temperature are grouped together to form the Weather Factors panel. The levels within each panel were chosen to represent the "basic-level" concepts important in ATC. Research in human learning and concept formation indicates that the basic level is the most natural level at which people think about concepts, as suggested by the fact that individuals label concepts most frequently at this level of generality (Rosch et al., 1976). (For example, if you see a dog, you will typically think about it in terms of "dog" (the basic level), rather than "animal" (the superordinate level) or "collie" (the subordinate level)). Constructing the levels of the mental model around the basic-level of categorization should thus facilitate knowledge organization and retention (Redding, 1990).

The order of the levels is based on importance, flow through time, or a hierarchical organization from most general to most specific. Because the nature of the information in the panels varies, the organizing criterion is necessarily different. For the same reason, the content of the information in each panel and level varies. The specific information contained within each level is represented as messages (see Figure 3). Each message includes various elements of information, called "parameters." For example, the message for the Altitude level is:

[aircraft ID, actual altitude, <altitude cleared to>]

Thus, the information within the altitude level would contain the identification of the aircraft and its altitude. It would also contain the altitude the aircraft had been cleared to, but only if the aircraft had, in fact, been cleared to another altitude; therefore, whether or not this parameter is included depends upon the circumstances.

Mental Model: Levels Within Category Panels (Continued)

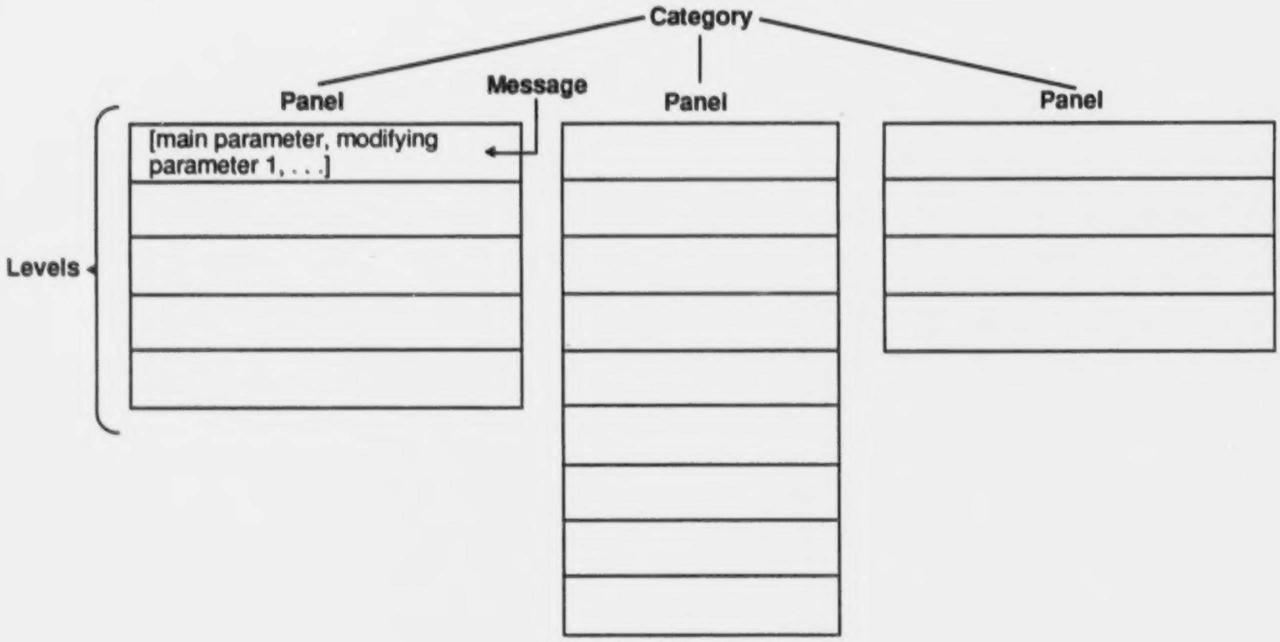
The format for a message is:

> [main parameter, modifying parameter 1, modifying parameter 2, ... modifying parameter n]; optional parameters are given as <parameter name>

In the remainder of this section, we discuss the individual panels of the mental model and their constituent levels in more detail.

Mental Model: Levels Within Category Panels (Continued)

Figure 3. Example Of The Organization Of The Mental Model


Category
Panel
Message
Panel
Panel
[main parameter, modifying parameter 1, . . .]
Levels

Sector Management Category

Sector Traffic Events Panel. This panel is divided into five levels, according to the general progress of an aircraft through the sector airspace. Aircraft enter the sector in Level 1 (Aircraft Entering Sector), then get recategorized into the appropriate middle level in Levels 2-4, and then get recategorized into Level 5 (Events Nearing Completion) after all control actions except handoff are completed. Aircraft may shift among Levels 2-4 as the situation changes, or may be part of more than one event. The organization of the middle levels is in order of the priority of handling they require. The levels are as follows:

1. **Aircraft Entering Sector**—This level includes aircraft that are entering the sector and require an accepting handoff from the adjacent sector or approach control, and aircraft that are now under sector control but have not yet been classified into any other events.

2. **Potential Conflictions**—This level includes events that, if not dealt with, will result in conflictions (separation violations, etc.). It includes conflicts with obstructions and with special use airspace. Examples of potential conflictions include:

    - Speed overtakes
    - Converging aircraft at the same altitude
    - One aircraft climbing or descending through the path of another aircraft
    - An aircraft converging on an obstruction, terrain, or a restricted/prohibited airspace

3. **Ongoing Events**—This level includes current events. Such events may require multiple steps and extend over a period of time, such as sequencing aircraft for arrival. Examples include:

    - Sequencing for arrival
    - Aircraft progression through a sector
    - Departure flows
    - Transitioning aircraft
    - Aircraft at a temporary altitude
    - Vectored aircraft
    - An aircraft near active special use airspace

Sector Management Category (Continued)

Sector Traffic Events Panel (Continued)

4. **Requests**—This level includes requests from other sector or approach controllers or aircraft that will alter or initiate events. Examples of pilot requests include:

   - Routing change
   - Altitude change
   - Destination change
   - Delay over a fix
   - Priority
   - Heading and/or speed change
   - IFR (Instrument Flight Rules) pickup
   - Specific type of approach or runway preference

   Examples of requests from adjacent controllers include:

   - Holding aircraft at a fix
   - Deviation from LOA (APREQ)
   - Pointout
   - Manual handoff

5. **Events Near Completion**—This level includes aircraft for which separation is ensured over the expected route through the sector and which will only require handoff, and aircraft that have been frequency switched but are still within the controller's airspace and are displayed on the PVD.

This panel contains events with various modifying parameters, the message for which is represented as:

Message: [Event Name, aircraft involved, criticality of event]

The criticality parameter contributes to the prioritization of tasks, with those of higher criticality levels having higher priority. Criticality of event is a rating of the consequences of not dealing with the event (see Human Technology, 1990, p. 55), as follows:

1. Safety
2. Separation violation
3. Procedural violation (e.g., not following LOA for handoff)
4. Efficiency for controller workload
5. Efficiency for pilot and aircraft route of flight

Sector Management Category (Continued)

Aircraft Data Panel. In general, the knowledge contained on this panel comprises a data base on all aircraft of interest to the controller. The levels are ordered according to a combination of importance and frequency of use. The first two levels indicate the aircraft's current position in three-dimensional space, so must be referred to frequently. The last level is infrequent; however, when there is an entry in this level, it is of primary importance and so its evaluation leads to posting an emergency message on the Ongoing Events level within the Sector Traffic Events panel. The Aircraft Data panel contains the following information for each aircraft:

1. **Altitude**—designates altitude stratum for each aircraft. Important for diagnosing critical events such as potential conflictions or sequencing problems. Actual altitude can be determined from the PVD or the FPS (Flight Progress Strip) if it is kept updated. "Altitude cleared to" indicates what altitudes "belong" to that aircraft. For example, an aircraft at 15,000 feet that has been cleared to land owns all altitudes from 15,000 feet to the ground. This parameter is only included if the aircraft is cleared to change altitudes.

   Message: [aircraft ID, actual altitude, <altitude cleared to>]

2. **Location**—designates current position of aircraft. This information will usually be a spatial representation as shown on the PVD; however, it can be designated in verbal form as latitude/longitude or as radial position relative to a fix (as on the FPS).

   Message: [aircraft ID, location]

3. **Traffic Type/Route**—individual aircraft categorized according to arrival to or departure from airports within the sector, and overflights over the sector, in conjunction with complete route information.

   Message: [aircraft ID, Route Type, Route]

4. **Time at Next Fix**—specific information about the aircraft's time at fix points in the sector. Important for prioritizing events and for diagnosing critical events such as potential conflictions or sequencing problems. This information is important for preplanning and is frequently used to organize FPS's in the bay.

   Message: [aircraft ID, fix, time]

5. **Aircraft Speed**—information about filed speed for each aircraft.

   Message: [aircraft ID, speed]

Sector Management Category (Continued)

Aircraft Data Panel (Continued)

6. **Assigned Restrictions**—rate restrictions on climb or descent or crossing restrictions that the controller has given to that aircraft, if any.

   Message: [aircraft ID, assigned restriction 1, <...assigned restriction n>]

7. **Aircraft Characteristics**—knowledge of aircraft performance parameters, such as maneuverability, climb rates, or speed capabilities, based on type of aircraft and airline carrier operational procedures. Important for developing plans and strategies for separating aircraft.

   Message: [aircraft ID, aircraft type, (jet, heavy, prop, or turboprop), <carrier, if commercial>, performance characteristic 1, ... performance characteristic n]

8. **Onboard Equipment**—type of NAVAID or communication equipment on the aircraft.

   Message: [aircraft ID, type of NAVAID equipment, type of communication equipment]

9. **Unusual Situations**—extraordinary aircraft characteristics such as equipment failures, fuel shortages, or pilot- or controller-declared emergencies. Types of emergencies include:

   - Lost aircraft
   - Sick on board (more critical if crew)
   - Mechanical structural emergencies
   - Fire
   - Hydraulics failure

   Message: [aircraft ID, unusual situation 1, <... unusual situation n>]

Sector Management Category (Continued)

Sector Control Plan Panel. This panel includes strategies for handling sector events (long-term plan) and the details of how to implement the plan through control actions (short-term plans). The organization of this panel is from general to specific and, within that, from most important to least important. The levels are as follows:

1. **Primary Long-Term Plan**—This level includes the general plan for the current and expected situation covering a timeframe of approximately 20 to 30 minutes in the future. The plans, both primary and backup, will change as new aircraft arrive in the sector and there is any other progress in the Sector Traffic Events panel. Also, messages will be posted here regarding the status of interrupted tasks and where and when they should be restarted.

   Message: [Event , strategy, criticality, approximate time]

   OR [Task name, subgoal to return to, restart trigger]

2. **Backup Long-Term Plan**—This level includes one or more alternative strategies to handle specific failures of primary plan above.

   Message: [Event, primary strategy, backup strategy, implementation condition]

3. **Primary Short-Term Plan**—This level includes sequence of control actions for immediate events within the next 1 to 5 minutes.

   Message: [Sequence number, control action, aircraft ID, event]

4. **Backup Short-Term Plan**—This level includes alternate plan(s) for control actions for immediate events within the next 1 to 5 minutes.

   Message: [Primary control action, backup control action, aircraft ID, implementation condition]

Conditions Category

The Conditions category panels contain information about factors that change the strategy or actions that would normally be taken to separate the given aircraft in the sector. Thus, these factors relate to increases or decreases in workload or the type of workload the controller experiences. The order of levels in all three of these panels is by importance/magnitude of impact upon workload.

The messages on these panels all have the same general form:

[Factor Description, Impact Importance, Strategy Impact , <time window>]

Impact importance is a three-level categorization of how much of the sector the factor affects, as follows:

1. High - affects the handling of almost all events.
2. Moderate - affects some of the events.
3. Low - affects only one or two events.

The impact on strategy is spelled out in the "strategy-impact" parameter. For example, upper winds may be strong enough that the controller must recompute all the vectors given to planes. The strategy-impact parameter might inform the controller to use a different strategy, such as "Vector all planes an extra ten degrees right." The "time window" parameter is included if the factor has a short-term impact.

Area And Sector Factors Panel. This panel contains the following three levels:

1. **Situation in Sector**—This level includes special conditions in the sector, such as change in the number of miles in trail on the approach to an airport, other flow control directives, SWAP (severe weather avoidance procedures), etc.
2. **Situation in Area/Adjacent Sectors**—This level includes special conditions in an area, such as closed runways, equipment outages, flow control directives, etc. This level differs from the one above in that it covers a larger area than just the specific sector.
3. **Staffing Factors**—This level includes factors unique to teamwork; for example, known working habits of d-side, adjacent sector or area controllers, or supervisors that influence strategy adopted for control. Also, this level covers the level of staffing as it affects workload.

Conditions Category (Continued)

Weather Factors Panel. This panel contains the following five levels:

1. **Thunderstorms**—The presence of thunderstorms affects workload for handling all aircraft in the area, including pilot weather deviations and requesting information from and providing information to pilots.

   Message: [Location, Level (1-5), Direction of movement, Impact Importance, Strategy Impact , <time window>]

2. **Turbulence**—As with thunderstorms, turbulence increases workload because the controller needs to alert pilots and provide altitude changes if possible.

   Message: [Location, Degree (light, moderate, severe, or extreme), Impact Importance, Strategy Impact , <time window>]

3. **Icing**—Icing affects lift. Workload impact includes providing information to pilots and responding to pilot requests to change altitudes to avoid icing.

   Message: [Location, Altitude stratum, Type, Impact Importance, Strategy Impact, <time window>]

4. **Upper Winds**—Winds impact speed of aircraft and vectoring techniques. The impact must be considered for all aircraft adding to workload.

   Message: [Location, Speed, Direction, Impact Importance, Strategy Impact , <time window>]

5. **Temperature**—Temperature affects aircraft performance (for example, climb rates in warm weather). Thus, in summer, the controller needs to adjust plans for different performance profiles.

   Message: [Season of the year (summer, not summer), Impact Importance, Strategy Impact]

Conditions Category (Continued)

Controller Factors Panel. This panel contains the following three levels:

1. **Traffic Volume/Complexity**—This level presents a characterization of the current overall level of traffic (e.g., sparse, moderate, or heavy traffic) in terms of numbers of aircraft and/or events. This characterization includes anticipation of future pushes and/or lulls, and also addresses the complexity of the traffic situation, such as intricacies of a cluster of planes to be sequenced. The number of planes a controller can handle is an individual judgment based on experience, expertise, and personality, as well as on the complexity of the traffic patterns. What is important is not the absolute number of planes that can be handled, but rather being able to accurately judge one's own capabilities and limits.

2. **Sector Equipment Status**—This level presents a characterization of the audibility and fidelity of the radio frequencies, the quality of the image on the radar scope, computer and telephone problems, etc. Problems with any workstation equipment limit the controller's ability to obtain information, communicate information, or otherwise control the sector, thus requiring strategy changes and workload reduction techniques.

3. **Personal Factors**—This level includes factors such as the individual controller's self-perception, a recent return from vacation or recent incident, and relations and interactions with coworkers and pilots.

Prerequisite Information Category

Sector Airspace Panel. This panel captures knowledge about the three-dimensional space of a particular sector in terms of natural features, manmade entities, and ATC constructs. Natural features include the geography of the region and topographic features such as mountains. Manmade entities include airports, NAVAID equipment, buildings, and runways.

ATC constructs refer to published arrivals, departures, and approaches, en route structures, and restricted areas. These constructs represent the principal locations for movement of aircraft in a manner similar to a highway on the ground. Thus, they are a primary component of the controller's internal model of the physical characteristics of the sector airspace.

This knowledge would be represented by a three-dimensional internal model of the sector airspace, reflecting its inherently spatial characteristics. The levels of knowledge within this panel are ordered from the general to the specific.

Prerequisite Information Category (Continued)

Sector Airspace Panel (Continued)

This panel contains the following six levels:

1. **Geography**—This level includes lateral and vertical limits of sector, airport locations, and NAVAID locations.

2. **En Route Structure**—This level includes approach control areas, altitude strata, and victor and jet airways ("highways in the sky").

3. **Published Arrivals, Departures, Approaches**

4. **Special Use Airspace**—This level includes Restricted Areas, Prohibited Areas, Military Operations Areas (MOA's), and aerial refueling and military routes.

5. **Topography**—This level includes terrain and manmade obstructions, Minimum Vectoring Altitudes (MVA's), and Minimum Obstruction Clearance Altitudes (MOCA's).

6. **Sector Traps Or Hot Spots**—This level includes known points or regions within a sector that are common points of potential confliction or pose special challenges to the separation of aircraft. To some degree, these are dealt with by the sector-specific techniques and strategies that appear in the Procedures panel.

The message format for all levels of this panel is:

Message: [characteristic description]

Procedures Panel. The ordering of information on this panel represents priority of application, and within that, general to sector-specific procedures. Procedures are the written rules that create the boundaries that constrain and define the actions of the air traffic controller. Specifically, ATC procedures are the rules that apply to controllers nationwide, while sector-specific procedures refer to the rules that govern a given sector. Techniques or strategies are methods for separating aircraft efficiently within the applicable rules. The General Strategies panel is intended to contain a catalogue of non-sector-specific methods that guide actions taken by controllers in response to the current situation captured in the Sector Management and Conditions categories.

Prerequisite Information Category (Continued)

Procedures Panel (Continued)

On the levels of the Procedures panel reside four types of procedural knowledge for En Route ATC:

1. **ATC Procedures** (applicable to prioritization)—This level presents codified ATC procedures (e.g., Air Traffic Control, 7110.65), including separation functions and methods, alert and advisory functions, precedence rules, rules for coordination and transfer of control, and other information relevant to ATC decisionmaking. This level does not include strip marking procedures, phraseology, beacon code assignments, and other necessary procedural knowledge that is not relevant to prioritization decisionmaking.

2. **Sector-Specific Procedures**—This level includes formal procedures such as Letters of Agreement (LOA's), Standard Operating Procedures, etc.

3. **General Techniques/Strategies**—This level includes methods for handling aircraft that capture expert approaches to generic problems such as workload management, sequencing, taking early control, etc.

4. **Sector-Specific Techniques/Strategies**—This level includes methods for effectively handling repetitive problems or situations that are sector-specific, for instance, problems based on the physical configuration or traffic type handled by the sector.

The message format within these panels is:

Message: [Procedure type, Procedure]

OR [Strategy type, Strategy, <Heuristics for when effective>]

Results: Task Decomposition

The goal of air traffic control is to provide for the safe, orderly, and expeditious flow of air traffic. As used in this document, a task is considered to be the next-level goal under this general goal of the job. Furthermore, a task is defined as a single unit of goal-directed activity that will execute to completion if uninterrupted. Thus, each task encapsulates a logically self-contained set of subgoals that are needed to attain the overall task goal. The criteria for defining a task were as follows:

- A single unit of goal-directed activity that will execute to completion if uninterrupted,
- A unit of cognitively-related decisions or ATC activities that exists across a wide spectrum of situations or scenarios,
- The goal is one level below the top-level job goal,
- The goal is not part of some other higher level goal (task), and
- The goal is not a variant of some other task (i.e., it has a different and unique triggering condition).

The tasks are not defined as strictly cognitive tasks; rather, they may be comprised of both behavioral and cognitive components. This analysis yielded 2 tasks that were primarily cognitive (Maintain Situation Awareness and Develop and Revise Sector Control Plan) and 10 tasks that were mixtures.

Tasks

The model extension resulted in 12 tasks as follows with the first 2 tasks (boxed in below) being the primary cognitive tasks mentioned above:

1. MAINTAIN SITUATION AWARENESS—Maintain complete understanding of current and projected positions of all aircraft in the sector, as well as all factors affecting aircraft separation, to determine events that must be dealt with or conditions that influence methods for handling events.

2. DEVELOP AND REVISE SECTOR CONTROL PLAN—Develop and revise a plan for controlling the sector that is current and comprehensive, and that handles contingencies.

3. RESOLVE AIRCRAFT CONFLICT—Evaluate potential conflictions and implement means to avoid them.

4. REROUTE AIRCRAFT—Change aircraft routes in response to requests or situational considerations.

Task Goals, Triggers, And Subgoals

Each task has a trigger that specifies a set of conditions under which the task should be initiated. The triggers are expressed as "AND" or "OR" statements describing all the conditions that must be true for the task to be performed. For example, a trigger to initiate a handoff could be "an aircraft 30 miles or less from the sector boundary AND no other critical events presently occurring."

For each task, the following components are also listed:

- The task goal defined (the task name is a short description of the goal),
- The task triggering conditions, specified both in a summary phrase and in terms of patterns of information in the mental model, and
- The subgoals of the task.

To perform a task, the controller must perform each of the task subgoals, which also may require the controller to refer back again to the mental model to get situational or strategic knowledge relevant for performing the subgoal. Additionally, performance of the subgoal itself may result in the acquisition of new information that must be incorporated into the mental model in order to update its contents. Thus, many subgoals have messages that specify what information should be added to which panel or level within the mental model, where the message is given as:

> [<message>, and the mental model reference is PANEL: *level*]
>
> (NOTE: Messages are only included with those cognitive subgoals that change the mental model. Thus, behavioral subgoals do not have messages, nor do the cognitive subgoals that do not alter or update the contents of the mental model.)

A subgoal or sub-subgoal may also have a condition associated with it. Conditions indicate constraints on execution of that subgoal, usually in terms of mental model contents. Some examples of conditions are: "IF adverse conditions" or "UNTIL conflict resolved."

The 12 tasks are presented in Table 1, along with their corresponding goals, triggers, and subgoals. The subgoals are generally performed sequentially (as indicated by the numbering in Table 1) until either all subgoals are completed or the task is interrupted. However, there are two types of subgoals that can differ from this basic sequential ordering:

1. Non-sequential subgoals—cases in which the subgoals may be pursued in any order. These subgoals are left unnumbered and are preceded by solid square bullets in Table 1.

Task Goals, Triggers, And Subgoals (Continued)

2. Mutually exclusive subgoals—cases in which only one of a set of subgoals is performed. A mutually exclusive set of subgoals is indicated by showing all members of the set preceded by a number sign (#).

The task subgoals are performed until either all subgoals are completed or the task is interrupted. There are three cases in which attention shifts and the task is interrupted prior to its completion:

1. Task Subordination—cases in which a task cannot be completed without interrupting it first to perform another task. These cases are indicated as "Subordinate to TASK __________ (NAME)." When this happens, the task is suspended, and a message to that effect is posted on the SCP (Sector Control Plan): Primary Long-Term Plan level within the mental model. Then when the second task is completed, attention shifts back to the first task, which resumes where it left off.

2. Task Suspension—cases in which a task cannot be completed until some other event happens (e.g., sequencing aircraft by vectoring, then having to wait to see if the control action resolved the problem). The "UNTIL" conditions on subgoals often result in a task suspension. When a task is suspended, a message to that effect is posted on the SCP: Primary Long-Term Plan level within the mental model, indicating the condition for task resumption and the subgoal at which the task should be resumed.

3. Task Capture—cases in which one task spontaneously overrides another in response to some urgent change in the problem state. In general, capturing of attention corresponds to those cases where a "red flag was raised" or a "mental alarm went off." It is activated by the occurrence of some triggering set of conditions in the mental model, and is usually the result of an emergency or urgent situation (e.g., potential conflict in the near future).

Table 1 on the following pages describes the 12 en route ATC tasks.

The mental model panels referred to are abbreviated as follows:

STE	Sector Traffic Events
AD	Aircraft Data
SCP	Sector Control Plan
ASF	Area and Sector Factors
WF	Weather Factors
CF	Controller Factors
SA	Sector Airspace
P	Procedures

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks

TASK 1: MAINTAIN SITUATION AWARENESS

Goal: Maintain complete understanding of current and projected positions of all aircraft in the sector, as well as all factors affecting aircraft separation, to determine events that must be dealt with or conditions that influence methods for handling events.

Trigger:

Accept control of a sector
AND do whenever possible

Subgoals:

- Evaluate aircraft data and determine events in sector ... do as frequently as possible

  Observe aircraft data on plan view display (PVD) and Flight Progress Strips (FPS)

  Message: [add, modify, or delete <data> on AD]

  Evaluate aircraft separation (use visualization, J-ball, other)

  Message: [if problem found, add <events> to STE]

  Determine traffic type ... IF new aircraft

  Message: [add <traffic type> to AD: Traffic Type/Route]

  Project aircraft routes in time/distance (using FPS, visualization, route readout function, or other aids)

  Message: [add <route> to AD: Traffic Type/Route]

  Evaluate aircraft routes with regard to future aircraft separation

  Message: [if problem found, add <events> to STE: Potential Conflictions]

  Evaluate aircraft type to determine characteristics and their impact on events

  Message: [add <characteristics> to AD: Aircraft Characteristics]

  Compare aircraft data with current sector situation understanding

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 1: MAINTAIN SITUATION AWARENESS (Continued)

Subgoals: (Continued)

Resolve inconsistencies between perceived aircraft data and current situation understanding ... IF any

Update sector traffic event understanding

Message: [add, modify, or delete <events> on STE]

Determine conditions in sector ... do periodically

Determine weather factors and evaluate their impact

Message: [add, modify, or delete <factors> on WF]

Review SIA board and determine impact of new factors

Message: [add, modify, or delete <factors> on ASF: Situation in Sector or Situation in Area/Adjacent Sectors]

Evaluate Flow Control directives and determine impact ... IF flow control directive in effect

Message: [add, modify, or delete <factors> on ASF: Situation in Sector or Situation in Area/Adjacent Sectors]

Determine traffic, personnel, and conditions in adjacent sectors/areas and evaluate impact of factors

Message: [add, modify, or delete <factors> on ASF]

Observe equipment status

Message: [add, modify, or delete <factors> on CF: Sector Equipment Status]

Update understanding of conditions affecting sector management

Message: [add, modify, or delete <factors> on ASF, WF, and CF]

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 1: MAINTAIN SITUATION AWARENESS (Continued)

Subgoals (Continued)

Determine effect of conditions on sector traffic events and sector control plan (Subordinate to DEVELOP AND REVISE SECTOR CONTROL PLAN)

- Evaluate changes in airspace features or procedures ... WHEN changes occur

  Evaluate/clarify new or changed airspace feature

  Message: [add, modify, or delete <data> on SA]

  Evaluate/clarify new procedure

  Message: [add, modify, or delete <data> on P: ATC Procedures or Sector-Specific Procedures]

- Evaluate workload and determine the need for assistance ... do periodically

  Evaluate workload to determine if assistance is needed

  Request assistance ... IF needed

- Maintain PVD readability ... IF overlapping data blocks

TASK 2: DEVELOP AND REVISE SECTOR CONTROL PLAN

Goal: Develop and revise a plan for controlling the sector that is current and comprehensive, and that handles contingencies.

Triggers:

new event not in plan

Message: [<event> on STE that is not in SCP]

OR change in event status (including additional aircraft involved)

Message: [change in <event parameter> on STE]

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 2: DEVELOP AND REVISE SECTOR CONTROL PLAN (Continued)

Trigger: (Continued)

OR emergency

Message: [<emergency type> on STE: Ongoing Events]

OR discrepancy with plan

Message: [<event parameters> on STE inconsistent with <plan element> on SCP]

OR change in Conditions

Message: [new <factor> or <factor parameter> on ASF or WF or CF]

Subgoals:

1. Develop/revise primary and backup long-term plans

Determine primary strategy for handling sector traffic events (with reference to other events and conditions, aircraft data, sector airspace knowledge, and procedural knowledge)

Message: [add, delete, or modify <strategies> on SCP: Primary Long-Term Plan]

Determine backup strategies for handling sector traffic events (including conditions for when to go to backup plan)

Message: [add, delete, or modify <strategies> on SCP: Backup Long-Term Plan]

2. Develop/revise primary and backup short-term plans

Determine control actions for next 1-5 minutes of primary long-term plan

Message: [add, delete, or modify <control actions> on SCP: Primary Short-Term Plan]

Determine backup control actions for specific primary control actions

Message: [add, delete, or modify <control actions> on SCP: Backup Short-Term Plan]

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 3: RESOLVE AIRCRAFT CONFLICT

Goal: Evaluate potential conflictions and implement means to avoid them.

Triggers:

Two or more aircraft converging on same latitude/longitude/altitude/airway

Message: [<aircraft ID1> and <aircraft ID2> {and ...<aircraft IDn>} in AD: Altitude, Location, and Traffic Type/Route]

OR two or more aircraft projected for same altitude at the same time at the same fix

Message: [<aircraft ID1> and <aircraft ID2> {and ...<aircraft IDn>} in AD: Altitude, Location, and Traffic Type/Route]

OR one aircraft in conflict with terrain or other obstruction

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route in reference to SA: Geography and Topography]

OR an aircraft in a traffic flow with different characteristics than the others (e.g., a slow-moving aircraft in a fast sector, or an aircraft going against the normal flow of traffic)

Message: [<aircraft ID> on AD: Altitude, Location, Traffic Type/Route, and Characteristics with reference to SA and STE]

Subgoals:

1. Evaluate aircraft route, altitude, time at next fix, goals, and characteristics reference sector traffic events and sector control plan ("Traffic Search")
2. Determine plan
3. Integrate conflict resolution plan into overall plan (Subordinate to DEVELOP AND REVISE SECTOR CONTROL PLAN)
4. Monitor aircraft progress to determine whether action is necessary ... IF aircraft might resolve situation without controller intervention

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 3: RESOLVE AIRCRAFT CONFLICT (Continued)

Subgoals: (Continued)

5. Call and coordinate with other sector ... IF necessary
6. Implement plan ... IF necessary
7. Monitor Conflict Resolution ... UNTIL resolved
8. Reevaluate situation and modify plan ... IF not resolved as planned

---

TASK 4: REROUTE AIRCRAFT

Goal: Change aircraft route in response to request or situational considerations.

Triggers:

Clearance request from pilot or adjacent controller

Message: [<clearance request> on STE: Requests]

OR IFR pickup request

Message: [<IFR pickup request> on STE: Requests]

OR weather in flight path (including thunderstorms or wind routing)

Message: [<thunderstorm> on WF: Thunderstorms OR <upperwinds> on WF: Upper Winds reference <aircraft ID> on AD: Altitude, Location, and Traffic Type/Route]

OR special use airspace in flight path

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference <MOA> or <MIA> on SA: Special Use Airspace]

OR flow control directive (including SWAP routing)

Message: [<flow control directive> on ASF: Situation in Sector]

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK: REROUTE AIRCRAFT (Continued)

Triggers: (Continued)

OR special situation (NAVAID outage, runway closing, etc.)

Message: [<special situation> on ASF: Situation in Sector or Situation in Area/Adjacent Sectors]

OR aircraft route in conflict with sector procedures (e.g., non-conformance with LOA's)

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference P: Sector-Specific Procedures]

OR change in sector control plan that requires change in an aircraft route

Message: [<reroute aircraft ID> on SCP: Primary Short-Term Plan]

Subgoals:

1. Evaluate route with reference to sector traffic events, conditions, sector control plan, and procedures
2. Call and coordinate ... IF necessary
3. Issue (or deny) clearance for rerouting (denial only in response to request)
4. Monitor for compliance with rerouting clearance ... IF issued

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 5: MANAGE ARRIVALS

Goal: Establish sequence of aircraft for arrival into an airport as well as ensure that all landing aircraft are on arrival routes.

Triggers:

Two or more aircraft converging on one airport for landing AND NOT sequenced for arrival

Message: [<sequence for arrival> event on STE: Ongoing Events]

OR one aircraft landing at an uncontrolled airport

Message: [<aircraft ID landing at airport X> event on STE: Ongoing Events with reference to AD, STE, and SA: Geography and Published Arrivals, Departures, Approaches]

OR one aircraft landing at a controlled airport

Message: [<aircraft ID landing at airport X> event on STE: Ongoing Events with reference to AD, STE, and SA: Geography and Published Arrivals, Departures, Approaches]

Subgoals:

1. Evaluate aircraft routes, timing, and characteristics with reference to sector traffic events, sector airspace, sector control plan, and procedures
2. Determine sequence for landing ... IF more than one aircraft
3. Determine vector/reroute for landing to implement sequencing ... IF more than one aircraft
4. Determine vector/reroute for landing to maintain aircraft on published arrival routes in accordance with procedures
5. Derive/revise primary and backup plan for sequencing/slowing/descending aircraft (reference the sector control plan)
6. Integrate with the sector control plan

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 5: MANAGE ARRIVALS (Continued)

Subgoals: (Continued)

7. Implement plan for sequencing/slowing/descending aircraft
8. Hand off to approach control as required or notify tower/flight service station (FSS) as necessary (Subordinate to INITIATE HANDOFF)
9. Monitor plan execution
10. Confirm landing OR cancel IFR ... IF uncontrolled airport

---

TASK 6: MANAGE DEPARTURES

Goal: Maintain safe and efficient departure flows and integration of departing aircraft with other traffic in the sector.

Triggers:

Receipt of Flight Strip for proposed departure

Message: [new <departure proposal> on STE: Aircraft Entering Sector]

OR departure notification

Message: [new <departure notification> on STE: Aircraft Entering Sector]

OR handoff accepted from Approach Control sector

Message: [new <departure> on STE: Ongoing Events]

OR departure clearance request from tower/FSS controller or pilot (at an uncontrolled airport)

Message: [<departure request> on STE: Requests]

OR departures anticipated AND adverse conditions

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 6: MANAGE DEPARTURES (Continued)

Triggers: (Continued)

Message: [<departures> on AD: Traffic Type/Route and <near future> on AD: Time at Next Fix and <adverse conditions> on ASF or WF]

OR APREQ from other controller

Message: [< request> on STE: Requests]

OR flow control directive/SWAP routing

Message: [<factors> on ASF: Situation in Sector or Situation in Area/Adjacent Sectors]

Subgoals:

# Manage departures from uncontrolled airports

Assess proposed departures for conformance with procedures

Assess potential confliction with current and projected sector traffic in light of conditions

Formulate clearance

Assess clearance for conformance to procedures

Issue clearance ... IF departure is approved

Assess clearance acknowledgment

Issue alternate instructions ... IF adverse conditions (weather, workload, level of traffic, flow control directive, or special situation in area)

Monitor aircraft and issue clearances to achieve final altitude ... IF aircraft departed

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 6: MANAGE DEPARTURES (Continued)

Subgoals: (Continued)

# Climb departures from approach control sectors to desired altitude ... IF handoff from approach control sector

  Assess potential confliction with current and projected sector traffic

  Monitor aircraft and issue clearances to achieve final altitude

# Restrict future departures ... IF adverse conditions (weather, workload, level of traffic, flow control directive, or special situation in area)

  Assess impact of conditions on workload and aircraft safety and route

  Issue departure restrictions based on conditions and amount and type of traffic

TASK 7: RECEIVE HANDOFF

Goal: Accept, delay, or deny handoff from a transferring controller.

Triggers:

Aircraft flashing on PVD

Message: [new <aircraft> on STE: Aircraft Entering Sector]

OR call for manual handoff

Message: [new <aircraft> on STE: Aircraft Entering Sector]

OR early handoff part of strategy

Message: [<reach out for aircraft> strategy on SCP: Primary Long-Term Plan]

OR aircraft not under control in radio contact

Message: [new <aircraft> on STE: Aircraft Entering Sector]

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 7: RECEIVE HANDOFF (Continued)

Subgoals:

1. Evaluate request reference sector traffic events and sector control plan
2. Call and coordinate ... IF restrictions or routing changes are needed prior to aircraft entering your airspace
3. Accept or delay handoff
4. Establish radar ID ... IF aircraft is nonradar off airport
5. Monitor for initiation of radio contact from aircraft
6. Verify aircraft altitude
7. Determine event(s) of which aircraft is a part

   Message: [reclassify from <event> on STE: Aircraft Entering Sector to <event> on STE: Potential Conflictions, Ongoing Events, or Events Nearing Completion]

TASK 8: RECEIVE POINTOUT

Goal: Assess and accept or decline a pointout from another controller.

Trigger:

Pointout from other traffic controller

Message: [new <pointout request> on STE: Requests]

Subgoals:

1. Evaluate request reference sector traffic events and sector control plan
2. Unconditionally accept, accept with restrictions, or deny pointout
3. Ensure separation between pointout aircraft and other sector aircraft ... IF accepted

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 9: INITIATE HANDOFF

Goal: Transfer aircraft radar identification and radio communications to the receiving controller.

Trigger:

Aircraft preparing to exit airspace (distance or time from boundary—distance can be greater when no traffic in route)

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route with reference to SA: Geography and STE and SCP]

Subgoals:

1. Determine when all control actions are complete
2. Coordinate with receiving controller ... IF coordination necessary
3. Initiate handoff to receiving controller
4. Confirm handoff acceptance from receiving controller OR confirm handoff verbally if non-automated handoff
5. Issue new radio frequency to pilot ... WHEN receiving sector accepts handoff

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 10: INITIATE POINTOUT

Goal: Initiate and complete pointout of aircraft to the receiving controller.

Trigger:

Aircraft to enter within 2.5 miles of protected airspace of another controller without transfer of control.

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route with reference to SA: Geography and STE and SCP]

Subgoals:

1. Evaluate appropriateness of pointout
2. Request pointout from appropriate controller
3. Route aircraft per other controller's request ... IF accepted

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TASK 11: ISSUE ADVISORY

Goal: Provide information to pilot or another controller.

Triggers:

Other aircraft traffic converging on an aircraft AND no critical tasks in progress

Message: [<aircraft ID1> on AD: Altitude, Location, and Traffic Type/Route reference <aircraft ID2> {and ...<aircraft IDn>} in AD: Altitude and Location]

OR weather system AND no critical tasks in progress

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference <thunderstorm> on WF: Thunderstorms OR <upperwinds> on WF: Upper Winds]

OR birdflight AND no critical tasks in progress

Task Goals, Triggers, And Subgoals (Continued)

Table 1. The 12 En Route Air Traffic Control Tasks (Continued)

TASK 11: ISSUE ADVISORY (Continued)

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference <birdflight at location X> on ASF: Situation in Sector]

OR situation in area (runway closure, NAVAID outage) AND no critical tasks in progress

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference <special situation> on ASF: Situation in Sector or Situation in Area/Adjacent Sectors]

OR potential impact of event on next sector AND no critical tasks in progress

Message: [<events> on STE reference ASF: Situation in Area/Adjacent Sectors]

Subgoals:

1. Determine that advisory is needed
2. Advise pilot of situation OR advise other controller
3. Assess pilot or other controller acknowledgment

TASK 12: ISSUE SAFETY ALERT

Goal: Provide mandatory safety warning to pilot.

Trigger:

Aircraft at an altitude that places it in unsafe proximity to terrain, obstructions, or other aircraft

Message: [<imminent confliction> on STE: Potential Conflictions]

Subgoals:

1. Issue alert to pilot
2. Provide pilot with alternate courses of action ... IF feasible
3. Monitor for pilot response

Task Triggers

The table below indicates what panels of the mental model were involved most frequently in providing all or part of the information to trigger a task. This analysis is useful in determining what aspects of the evolving situation should be monitored most closely to determine when to shift attention to a task.

The number of times each mental model panel was responsible for the primary or secondary part of a trigger is indicated below.

		Primary Trigger: # instances	Secondary Trigger: # instances
SECTOR MANAGEMENT	Sector Traffic Events	18	3
	Aircraft Data	13	3
	Sector Control Plan	1	2
CONDITIONS	Conditions (ASF & WF)	4	5
	Controller Factors	0	0
PREREQUISITE INFORMATION	Sector Airspace	0	5
	Procedures	0	1

As might be expected, changes in Sector Traffic Events and Aircraft Data (mostly Altitude and Location, and to a lessor extent, Route) are the changes that most frequently provide information for triggering a task. Controllers referred to these panels twice as often as all the other panels combined. Changes in Conditions trigger a few tasks, but generally are secondary contributors. No tasks are directly triggered by the Controller Factors panel. Prerequisite Information panels do not directly trigger tasks. However, Prerequisite Information is a secondary factor in a few triggers.

Table 2 on the following pages presents all the task triggers organized in terms of the mental model panel and level that provide the information specified in the trigger, and the task that they trigger. This listing may be useful for part-task training in relating task triggers to the information within the mental model and for organizing triggers around problem types (tasks) and the mental model structure.

Task Triggers (Continued)

Table 2. Relationships Of Task Triggers To Mental Model Components And Tasks

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ALWAYS ACTIVE

Accept control of a sector AND do whenever possible

(MAINTAIN SITUATION AWARENESS)

SECTOR MANAGEMENT - SECTOR TRAFFIC EVENTS

Task Trigger: Aircraft flashing on PVD

Message: [new <aircraft> on STE: Aircraft Entering Sector]
Task: (RECEIVE HANDOFF)

Task Trigger: Call for manual handoff

Message: [new <aircraft> on STE: Aircraft Entering Sector]
Task: (RECEIVE HANDOFF)

Task Trigger: Receipt of Flight Strip for proposed departure

Message: [new <departure proposal> on STE: Aircraft Entering Sector]
Task: (MANAGE DEPARTURES)

Task Trigger: Departure notification

Message: [new <departure notification> on STE: Aircraft Entering Sector]
Task: (MANAGE DEPARTURES)

Task Trigger: Emergency

Message: [<emergency type> on STE: Ongoing Event]
Task: (DEVELOP AND REVISE SECTOR CONTROL PLAN)

Task Trigger: Aircraft at an altitude that places it in unsafe proximity to terrain, obstructions, or other aircraft

Message: [<imminent confliction> on STE: Potential Conflictions]
Task: (ISSUE SAFETY ALERT)

Task Triggers (Continued)

Table 2. Relationships Of Task Triggers To Mental Model Components And Tasks (Continued)

SECTOR MANAGEMENT - SECTOR TRAFFIC EVENTS (Continued)

Task Trigger: Two or more aircraft converging on one airport for landing AND NOT all sequenced for arrival

Message: [<sequence for arrival> event on STE: Ongoing Events]
Task: (MANAGE ARRIVALS)

Task Trigger: One aircraft landing at an uncontrolled airport

Message: [<aircraft ID landing at airport X> event on STE: Ongoing Events with reference to AD, STE, and SA: Geography and Published Arrivals, Departures, Approaches]
Task: (MANAGE ARRIVALS)

Task Trigger: One aircraft landing at a controlled airport

Message: [<aircraft ID landing at airport X> event on STE: Ongoing Events with reference to AD, STE, and SA: Geography and Published Arrivals, Departures, Approaches]
Task: (MANAGE ARRIVALS)

Task Trigger: Clearance request from pilot or adjacent controller

Message: [<clearance request> on STE: Requests]
Task: (REROUTE AIRCRAFT)

Task Trigger: IFR pickup request

Message: [<IFR pickup request> on STE: Requests]
Task: (REROUTE AIRCRAFT)

Task Trigger: Departure clearance request from tower controller or pilot (at an uncontrolled airport)

Message: [<departure request> on STE: Requests]
Task: (MANAGE DEPARTURES)

Task Triggers (Continued)

Table 2. Relationships Of Task Triggers To Mental Model Components And Tasks (Continued)

SECTOR MANAGEMENT - SECTOR TRAFFIC EVENTS (Continued)

Task Trigger: APREQ from other controller

Message: [< request> on STE: Requests]
Task: (MANAGE DEPARTURES)

Task Trigger: Pointout from other traffic controller

Message: [new <pointout request> on STE: Requests]
Task: (RECEIVE POINTOUT)

Task Trigger: Change in event status (including additional aircraft involved)

Message: [change in <event parameter> on STE]
Task: (DEVELOP AND REVISE SECTOR CONTROL PLAN)

Task Trigger: Potential impact of event on next sector AND no critical tasks in progress

Message: [<events> on STE reference ASF: Situation in Area/Adjacent Sectors]
Task: (ISSUE ADVISORY)

Task Trigger: New event not in plan

Message: [<event> on STE that is not in SCP]
Task: (DEVELOP AND REVISE SECTOR CONTROL PLAN)

Task Trigger: Discrepancy with plan

Message: [<event parameters> on STE inconsistent with <plan element> on SCP]
Task: (DEVELOP AND REVISE SECTOR CONTROL PLAN)

Task Triggers (Continued)

Table 2. Relationships Of Task Triggers To Mental Model Components And Tasks (Continued)

SECTOR MANAGEMENT - SECTOR TRAFFIC EVENTS (Continued)

Task Trigger: An aircraft in a traffic flow with different characteristics than the others (e.g., a slow-moving aircraft in a fast sector, or an aircraft going against the normal flow of traffic)

Message: [<aircraft ID> on AD: Altitude, Location, Traffic Type/Route, and Characteristics with reference to SA and STE]
Task: (RESOLVE AIRCRAFT CONFLICT)

Task Trigger: Aircraft preparing to exit airspace (distance or time from boundary—distance can be greater when no traffic in route)

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route with reference to SA: Geography and STE and SCP]
Task: (INITIATE HANDOFF)

Task Trigger: Aircraft to enter within 2.5 miles of protected airspace of another controller without transfer of control

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route with reference to SA: Geography and STE and SCP]
Task: (INITIATE POINTOUT)

SECTOR MANAGEMENT - AIRCRAFT DATA

Task Trigger: Two or more aircraft converging on same latitude/longitude/altitude/airway

Message: [<aircraft ID1> and <aircraft ID2> {and ...<aircraft IDn>} in AD: Altitude, Location, and Traffic Type/Route]
Task: (RESOLVE AIRCRAFT CONFLICT)

Task Trigger: Two or more aircraft projected for same altitude at the same time at the same fix

Message: [<aircraft ID1> and <aircraft ID2> {and ...<aircraft IDn>} in AD: Altitude, Location, and Traffic Type/Route]
Task: (RESOLVE AIRCRAFT CONFLICT)

Task Triggers (Continued)

Table 2. Relationships Of Task Triggers To Mental Model Components And Tasks (Continued)

SECTOR MANAGEMENT - AIRCRAFT DATA (Continued)

Task Trigger: One aircraft in conflict with terrain or other obstruction

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route in reference to SA: Geography and Topography]
Task: (RESOLVE AIRCRAFT CONFLICT)

Task Trigger: An aircraft in a traffic flow with different characteristics than the others (e.g., a slow-moving aircraft in a fast sector, or an aircraft going against the normal flow of traffic)

Message: [<aircraft ID> on AD: Altitude, Location, Traffic Type/Route, and Characteristics with reference to SA and STE]
Task: (RESOLVE AIRCRAFT CONFLICT)

Task Trigger: Special use airspace in flight path

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference <MOA> or <MIA> on SA: Special Use Airspace]
Task: (REROUTE AIRCRAFT)

Task Trigger: Aircraft route in conflict with sector procedures (e.g., nonconformance with LOA's)

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference P: Sector-Specific Procedures]
Task: (REROUTE AIRCRAFT)

Task Trigger: Aircraft preparing to exit airspace (distance or time from boundary—distance can be greater when no traffic in route)

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route with reference to SA: Geography and STE and SCP]
Task: (INITIATE HANDOFF)

Task Triggers (Continued)

Table 2. Relationships Of Task Triggers To Mental Model Components And Tasks (Continued)

SECTOR MANAGEMENT - AIRCRAFT DATA (Continued)

Task Trigger: Aircraft to enter within 2.5 miles of protected airspace of another controller without transfer of control

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route with reference to SA: Geography and STE and SCP]
Task: (INITIATE POINTOUT)

Task Trigger: Other aircraft traffic converging on an aircraft AND no critical tasks in progress

Message: [<aircraft ID1> on AD: Altitude, Location, and Traffic Type/Route reference <aircraft ID2> {and ...<aircraft IDn>} in AD: Altitude and Location]
Task: (ISSUE ADVISORY)

Task Trigger: Weather system AND no critical tasks in progress

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference <thunderstorm> on WF: Thunderstorms OR <upperwinds> on WF: Upper Winds]
Task: (ISSUE ADVISORY)

Task Trigger: Weather in flight path (including thunderstorms or wind routing)

Message: [<thunderstorm> on WF: Thunderstorms OR <upperwinds> on WF: Upper Winds reference <aircraft ID> on AD: Altitude, Location, and Traffic Type/Route]
Task: (REROUTE AIRCRAFT)

Task Trigger: Birdflight AND no critical tasks in progress

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference <birdflight at location X> on ASF: Situation in Sector]
Task: (ISSUE ADVISORY)

Task Triggers (Continued)

Table 2. Relationships Of Task Triggers To Mental Model Components And Tasks (Continued)

SECTOR MANAGEMENT - AIRCRAFT DATA (Continued)

Task Trigger: Situation in area (runway closure, NAVAID outage) AND no critical tasks in progress

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference <special situation> on ASF: Situation in Sector or Situation in Area/Adjacent Sectors]
Task: (ISSUE ADVISORY)

Task Trigger: Departures anticipated AND adverse conditions

Message: [<departures> on AD: Traffic Type/Route and <near future> on AD: Time at Next Fix and <adverse conditions> on ASF or WF]
Task: (MANAGE DEPARTURES)

Task Trigger: One aircraft landing at an uncontrolled airport

Message: [<aircraft ID landing at airport X> event on STE: Ongoing Events with reference to AD, STE, and SA: Geography and Published Arrivals, Departures, Approaches]
Task: (MANAGE ARRIVALS)

Task Trigger: One aircraft landing at a controlled airport

Message: [<aircraft ID landing at airport X> event on STE: Ongoing Events with reference to AD, STE, and SA: Geography and Published Arrivals, Departures, Approaches]
Task: (MANAGE ARRIVALS)

Task Triggers (Continued)

Table 2. Relationships Of Task Triggers To Mental Model Components And Tasks (Continued)

SECTOR MANAGEMENT - SECTOR CONTROL PLAN

Task Trigger: Early handoff part of strategy

Message: [<reach out for aircraft> strategy on SCP: Primary Overall Strategy]
Task: (RECEIVE HANDOFF)

Task Trigger: Aircraft preparing to exit airspace (distance or time from boundary—distance can be greater when no traffic in route)

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route with reference to SA: Geography and STE and SCP]
Task: (INITIATE HANDOFF)

Task Trigger: Aircraft to enter within 2.5 miles of protected airspace of another controller without transfer of control

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route with reference to SA: Geography and STE and SCP]
Task: (INITIATE POINTOUT)

CONDITIONS

Task Trigger: Change in Conditions

Message: [new <factor> or <factor parameter> on ASF or WF or CF]
Task: (DEVELOP AND REVISE SECTOR CONTROL PLAN)

Task Trigger: Flow control directive (including SWAP routing)

Message: [<flow control directive> on ASF: Situation in Sector]
Task: (REROUTE AIRCRAFT)

Task Trigger: Special situation (NAVAID outage, runway closing, etc.)

Message: [<special situation> on ASF: Situation in Sector or Situation in Area/Adjacent Sectors]
Task: (REROUTE AIRCRAFT)

Task Triggers (Continued)

Table 2. Relationships Of Task Triggers To Mental Model Components And Tasks (Continued)

CONDITIONS (Continued)

Task Trigger: Birdflight AND no critical tasks in progress

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference <birdflight at location X> on ASF: Situation in Sector]
Task: (ISSUE ADVISORY)

Task Trigger: Situation in area (runway closure, NAVAID outage) AND no critical tasks in progress

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference <special situation> on ASF: Situation in Sector or Situation in Area/Adjacent Sectors]
Task: (ISSUE ADVISORY)

Task Trigger: Flow control directive/SWAP routing

Message: [<factors> on ASF: Situation in Sector or Situation in Area/Adjacent Sectors]
Task: (MANAGE DEPARTURES)

Task Trigger: Potential impact of event on next sector AND no critical tasks in progress

Message: [<events> on STE reference ASF: Situation in Area/Adjacent Sectors]
Task: (ISSUE ADVISORY)

Task Trigger: Weather system AND no critical tasks in progress

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference <thunderstorm> on WF: Thunderstorms OR <upperwinds> on WF: Upper Winds]
Task: (ISSUE ADVISORY)

Task Triggers (Continued)

Table 2. Relationships Of Task Triggers To Mental Model Components And Tasks (Continued)

CONDITIONS (Continued)

Task Trigger: Weather in flight path (including thunderstorms or wind routing)

Message: [<thunderstorm> on WF: Thunderstorms OR <upperwinds> on WF: Upper Winds reference <aircraft ID> on AD: Altitude, Location, and Traffic Type/Route]
Task: (REROUTE AIRCRAFT)

Task Trigger: Departures anticipated AND adverse conditions

Message: [<departures> on AD: Traffic Type/Route and <near future> on AD: Time at Next Fix and <adverse conditions> on ASF or WF]
Task: (MANAGE DEPARTURES)

Task Trigger: One aircraft landing at an uncontrolled airport

Message: [<aircraft ID landing at airport X> event on STE: Ongoing Events with reference to AD, STE, and SA: Geography and Published Arrivals, Departures, Approaches]
Task: (MANAGE ARRIVALS)

PREREQUISITE INFORMATION - SECTOR AIRSPACE

Task Trigger: One aircraft landing at a controlled airport

Message: [<aircraft ID landing at airport X> event on STE: Ongoing Events with reference to AD, STE, and SA: Geography and Published Arrivals, Departures, Approaches]
Task: (MANAGE ARRIVALS)

Task Trigger: One aircraft in conflict with terrain or other obstruction

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route in reference to SA: Geography and Topography]
Task: (RESOLVE AIRCRAFT CONFLICT)

Task Triggers (Continued)

Table 2. Relationships Of Task Triggers To Mental Model Components And Tasks (Continued)

PREREQUISITE INFORMATION - SECTOR AIRSPACE (Continued)

Task Trigger: An aircraft in a traffic flow with different characteristics than the others (e.g., a slow-moving aircraft in a fast sector, or an aircraft going against the normal flow of traffic)

Message: [<aircraft ID> on AD: Altitude, Location, Traffic Type/Route and Characteristics with reference to SA and STE]
Task: (RESOLVE AIRCRAFT CONFLICT)

Task Trigger: Special use airspace in flight path

Message: [<aircraft ID> on AD: Altitude, Location, and Traffic Type/Route reference <MOA> or <MIA> on SA: Special Use Airspace]
Task: (REROUTE AIRCRAFT)

PREREQUISITE INFORMATION - PROCEDURES

Task Trigger: Aircraft route in conflict with sector procedures (e.g., nonconformance with LOA's)

Message: [<aircraft ID> on AD: Traffic Type/Route reference P: Sector-Specific Procedures]
Task: (REROUTE AIRCRAFT)

Results: Perceptual Events

In addition to situational changes resulting from the performance of a task subgoal, situational changes also occur as the result of actions that are external to the controller. Events occur that are reflected through the PVD (e.g., new symbols appear as aircraft enter sector), flight strips, automated messages, communications from pilots or other controllers, etc. The controller detects these events and incorporates them into his or her mental model of the overall ATC situation.

Perceptual events consist of only a trigger and a message that it adds to the mental model. Unlike the 12 tasks, their conditions/triggers are not based on the current contents of the mental model, but instead are based on workstation-based information, such as a new data block appearing on the PVD. Once this information is added to the mental model, however, it may affect the flow of attention because the task triggers are based on patterns of information in the mental model. The perceptual events provide the mechanism whereby situational changes directly affect task execution. (Perceptual events provide the mechanism for data-driven processes, while the tasks themselves provide for goal-driven processes).

Table 3 lists the perceptual events, indicating what information is added to the mental model for each type of event.

Results: Perceptual Events (Continued)

Table 3. Perceptual Events

1. Aircraft data from PVD

   Message: [add, modify, or delete <data> on AD]

2. Aircraft data from FPS

   Message: [add, modify, or delete <data> on AD]

3. Other automated messages on system

   a. automated handoffs
   Message: [add, modify, or delete <events> on STE: Aircraft Entering Sector]

   b. MSAW or conflict alerts
   Message: [add, modify, or delete <events> on STE: Potential Conflictions]

4. Verbal communication with pilots

   Messages: [add, modify, or delete <data> on AD]

   [add, modify, or delete <requests> on STE: Requests]

   [add, modify, or delete <events> on STE]

   [add, modify, or delete <factors> on ASF or WF]

5. Verbal communication with adjacent controllers

   Messages: [add, modify, or delete <data> on AD]

   [add, modify, or delete <requests> on STE: Requests]

   [add, modify, or delete <events> on STE]

   [add, modify, or delete <factors> on ASF or WF]

6. Verbal communication with others in center (supervisors, etc.)

   Messages: [add, modify, or delete <factors> on ASF, WF, or CF]

   [add, modify, or delete <data> on SA or P]

   [add, modify, or delete <plan elements> on SCP]

   [add, modify, or delete <data> on AD]

   [add, modify, or delete <events> on STE]

Results: Perceptual Events (Continued)

This listing may be useful for part-task training development around relating perceptual events to the appropriate mental model panel or category. Research on visual scanning in ATC suggests that one frequent source of error may be a failure to use the information contained in these perceptual events to update the mental model contents (see Section V of this report). One important training issue is attention training—learning which of the available data to pay attention to. For example, not all of the information in a full data block on the PVD is equally important at all times. Training on the mental model may help controllers to refine their selective attention because attention should be directed to data that fill in important categories of the mental model. Training can be given in scanning techniques most effective for perceiving/identifying the important perceptual events.

Results: Validation

The validation data provided construct validation for the mental model and task decomposition framework. The most compelling evidence for the validity of the mental model categories is that the participants described their categorizations and depictions of the sector events at the same level of specificity as the levels within the mental model (i.e., the "basic level," for example: Route, Altitude, etc. See Figures 11-14, Section IV). (Recall that individuals will typically spontaneously categorize and label things at the "basic level.") This evidence suggests that controllers do think about the job in the same terms as described by the levels within the mental model. The validation data demonstrated that the model is complete and that the breakdown of panels and levels matched controllers' descriptions of their thinking. The discussion below provides examples taken from the validation study, relating to each of the panels within the mental model.

Validation: Sector Management Category

The dynamic elements of sector knowledge mapped cleanly into the three Sector Management Panels: Sector Traffic Events, Aircraft Data, and Sector Control Plan. Controllers used information about individual aircraft and groups of aircraft to define events, such as conflictions, departures, arrivals, overflights, and requests. Controllers constructed short-term plans and long-term plans in the forms of strategies and techniques to deal with these events. Examples for each of the panels are given below.

Validation: Sector Management Category (Continued)

- **Sector Traffic Events Panel**

  The study validated the structure and contents of this panel in several ways (see Figure 11, Section IV, for an example). Entrance, transit through, and exit from the sector were accurately depicted by the progression of levels in the panel. Aircraft being handed off to the sector enter the controller's awareness as Aircraft Entering Sector. After accepting handoffs on the aircraft, they are categorized into events involving Potential Conflictions, Ongoing Events, Requests, and Events Nearing Completion. The ensuing dynamics of the evolving scenario sometimes necessitate the recategorization of aircraft into other events, thereby moving the aircraft into a different event message residing in a different level of the panel. For example, an aircraft perceived as an event nearing completion may come into conflict with a new aircraft in the sector. In this case, both of these aircraft become part of an event involving potential confliction. When control actions on an aircraft are complete, the aircraft enters the Events Nearing Completion level. Control of these aircraft is transferred as expeditiously as workload permits. Additionally:

  - The controller used data about aircraft to categorize individual, pairs, or clusters of aircraft as events such as potential conflictions or ongoing events. For example, traffic type and route lead to an aircraft being categorized as part (or all) of an ongoing event such as a departure flow or arrival sequence.

  - The data substantiated the need to deal with complex events such as departure and arrival management, and conflict resolution, via multiple tasks. This flow among tasks occurred either because the trigger for another task was satisfied and that new task captured control, or because the original task was suspended pending further changes in the scenario and then resumed at a later time.

  - Efficient handling of a traffic event results in that aircraft's expeditious transition to the Events Nearing Completion level. Expert control strategies place aircraft in this category as quickly as possible to reduce sector traffic volume and complexity.

Validation: Sector Management Category (Continued)

- **Aircraft Data Panel**

The salient Aircraft Data employed in the scenario were altitude, location, traffic type/route, and speed. These data were also the way in which controllers classified the aircraft (see Figure 11, Section IV, for example). The results reveal the manner in which this information was used to categorize the aircraft as a traffic event:

- Traffic type and route defined the type of ongoing event, when appropriate.
- Altitude, location, and speed were primary factors in assessing potential conflictions. (One difference between controllers was that the first participant used altitude to resolve potential conflictions whereas the second participant used vectoring in the same situation.)
- Requests were assessed in reference to altitude, location, and traffic type and route.

Thus, the categories of aircraft data and their ordering according to importance within this panel was corroborated by the study (see Figure 12, Section IV, for an example).

- **Sector Control Plan Panel**

Long-term plans and short-term plans were developed and revised as the controllers worked the sector airspace (see Figure 13, Section IV, for an example). Under conditions of heavy workload, the long-term plan may be abandoned while the controller is forced to "react to traffic," that is, to work entirely from a short-term plan. In times of low workload, planning was not mentioned by the controllers because definitive, efficient control actions provided unequivocal separation of traffic.

Examples of planning in reference to specific traffic event types include:

- Aircraft Entering Sector: Taking early control of aircraft when it will reduce overall sector workload. Workload level can also be controlled by delaying taking handoffs as long as possible (within procedural guidelines).
- Departures (Ongoing Event): Holding a second aircraft in a departure flow on the ground until the first aircraft had attained an altitude that assured its separation with the first aircraft.
- Potential Conflictions (Ongoing Event): Using altitude adjustment to handle potential conflictions in reference to the altitude changes necessary to maintain other aircraft on approaches to airports, departures from airports, and with minimal interference with overflights.

Validation: Sector Management Category (Continued)

- **Sector Control Plan Panel** (Continued)

  - Events Nearing Completion: Implementing control actions that will expedite assignment of aircraft to this panel level. Including a comprehensive view in assessing the impact of other current and upcoming sector events enables the controller to minimize the number of control actions overall and thus reduce workload.

Validation: Conditions Category

Factors that increased workload were captured by the levels on the three Conditions panels—Area and Sector Factors, Weather Factors, and Controller Factors (see Figure 14, Section IV, for an example)-as described below.

- **Area and Sector Factors Panel**

  Staffing Factors drove up the workload of the controller (in the DYSIM environment) because no relief was provided by a radar associate controller for initial coordination, acceptance and transfer of control of aircraft, etc.

- **Weather Factors Panel**

  Weather Factors over MIO triggered additional tasks in instances of Issuing Advisories. As predicted by the model, the controller did not issue advisories when other critical tasks were in progress.

- **Controller Factors Panel**

  The perception of high levels of Traffic Volume/Complexity caused the controller to delay takeoffs and vectoring for landing, thus increasing the number of control actions necessary to accomplish these tasks. Sector Equipment Status (failure) resulted in the need to coordinate with another sector in regard to inaccurately displayed PVD data.

  Personal Factors contributed to modification of strategies by controllers. One controller said he always modified his general control strategy after returning from vacation, by slowing the pace of the sector, limiting traffic complexity, and using more preplanning.

Validation: Prerequisite Information Category

Noteworthy examples of the use of prerequisite knowledge in the scenario are described below:

- **Sector Airspace Panel**

  The scenario involved arrivals into Dallas via a new approach and a new airport southwest of Tulsa. The first participant used the route readout function of the PVD to locate these entities in the sector airspace, thus including knowledge of these features in strategy and planning regarding sector events.

- **Procedures Panel**

  Compliance with global ATC procedures is implicit in all tasks (e.g., aircraft must always be separated by certain vertical and horizontal distances, handoffs must occur at prescribed distances from the sector boundary, etc.). The most obvious example of the use of procedures involved control actions to ensure compliance with the LOA with the Tulsa approach sector.

Validation: Task Decomposition

The 12 tasks in our task decomposition accommodated all 46 task events that occurred in the scenario. Thus, the tasks in the task decomposition were able to account for all the task events and controller operations. The performance of a task was initiated when the triggers for that task were present, which supports the validity of the task triggers. The validation also illustrated the flow of attention as specified by the task subordination and suspension rules associated with certain task subgoals.

Summary

To summarize the results, an elaborated and refined mental model and a task decomposition were developed. The mental model depicts a generic expert-typical representation of the knowledge required to support performance of the tasks. The structure of the mental model implies a conceptual framework used by the controller for organizing ATC knowledge and implies a strategy for applying the knowledge in job conduct. A significant body of research indicates the importance of effective mental models for training and task performance (see Gentner & Stevens, 1983). Harwood, Roske-Hofstrand, & Murphy (1991) point out that one factor contributing to the difficulty of ATC is the complex interrelationships among the various tasks and knowledge categories. The current mental model provides an efficient organizer of this complexity, and "provides a context for the controller to interpret, synthesize, and organize incoming information and thus is key to maintaining the controller's awareness of the situation." One study, for instance, found that good performers in physics focus more upon situational knowledge (Ferguson-Hessler & de Jong, 1990) as provided by the mental model. The knowledge base of good performers is organized around a mental model structure, whereas poor performers lack such an underlying organization (de Jong & Ferguson-Hessler, 1986; Ferguson-Hessler & de Jong, 1990).

Training can be facilitated by the use of the mental model. The mental model provides the structure to support expert knowledge, and teaching that structure to trainees should expedite the learning, retention, and utilization of that knowledge. The mental model divides ATC knowledge into eight panels representing different kinds of knowledge needed for ATC decisionmaking. The validation study provided construct validity for the mental model, as the breakdown of panels and levels matched the controllers' description of their thinking about the job. Because the mental model contains the important knowledge categories found to support task performance, and also because the mental model represents expert-typical mental categorizations, controllers can be taught to think about tasks (particularly the Maintain Situation Awareness task) with reference to the model. An FAA task group report (FAA, 1987) identified failure to recall information about aircraft under control and/or ATC procedures as a cause of a number of operational errors, and concluded that memory aids are needed. The same report identified the need for controllers to develop better knowledge and task organization. The mental model provides organization for ATC and sector knowledge, and this efficient organization promotes recall.

The organization of the Sector Management category implies a specific decisionmaking flow, as follows. The controller perceives data from the PVD, from flight progress strips, and from communication with pilots about individual aircraft. The controller then processes these data about individual aircraft and categorizes them into events that must be handled (as part of the Maintain Situation Awareness task). An event is a high-level construct that represents an important control situation involving one or more aircraft. The long-term plan for controlling the sector is devised to handle events (represented as the Primary and Backup Long-Term Plan levels) and then is translated into a detailed plan of specific control actions involving individual aircraft (represented as the Primary and Backup Short-Term Plan levels).

Summary
(Continued)

Decisionmaking involves events rather than individual aircraft. Thus, by learning procedures and strategies for event types, the amount of information that must be remembered at any one time is significantly less than if all data about each aircraft had to be actively considered to make decisions. The dynamic aspects of the mental model, including event types, are assumed to be either in working memory or easily accessible from long-term memory. The capacity of working memory is not large enough for even the complete Sector Management category contents to be in working memory at one time. However, the critical events, their status, some relevant data on the aircraft involved, and the plan for dealing with the events most likely will be in working memory. Of course, experts will have larger chunks, resulting in a greater effective working memory capacity. Practice thinking about the domain using this mental model should enhance organization and information chunking for all levels of controllers, particularly novices.

The task decomposition resulted in a listing of 12 tasks, 10 of which include both cognitive and behavioral subgoals. Validation was also obtained for the task decomposition, as the 12 tasks accommodated and accounted for all scenario events and controller operations. Each task consists of a task trigger and task subgoals. The subgoals involving cognitive operations that update the mental model have messages, indicating the data that are added to the mental model once the subgoal has been performed. Because the task decomposition is goal-based, the tasks correspond to goals rather than the behavioral action sequences in standard, behavioral task analyses. The task decomposition can provide a framework for part-task training and teaching by problem types. Delineation of subgoals within the tasks allows instructors to teach subgoal recognition explicitly.

The 2 primary cognitive tasks, Maintain Situation Awareness and Revise and Update Sector Control Plan, are the two tasks most central to effective en route ATC and are the aspects of ATC most characteristic of expertise. These 2 tasks are often done in conjunction with one another, and attention generally flows from these 2 primary tasks to the other 10 tasks. The Maintain Situation Awareness task represents active monitoring and scanning to update the mental model, so it is returned to whenever possible.

The task triggers were identified for each task, and a listing was provided that organized all the task triggers in terms of the mental model panel and level that provide the information specified in the trigger. This listing may be useful for developing part-task training around trigger recognition and task types. Because triggers tell which task to execute when, they include an implicit prioritization scheme. Training in task trigger recognition will increase speed of response, reduce workload, and help ensure effective task prioritization. In learning task triggers, trainees will be learning the situational context for task performance and prioritization decisionmaking.

Summary
(Continued)

The Sector Traffic Events and Aircraft Data panels were found to be the mental model panels that most frequently provide information for triggering a task. This finding suggests that they are the panels within the mental model that should be evaluated and updated the most often, and should receive the primary emphasis in training. Altitude, location, and route were the specific levels most often involved in triggering a task. The task triggers were also validated, in that the performance of a task was initiated when the triggers for that task were present.

Finally, perceptual events were identified. These are situational changes that occur unrelated to the performance of a task. They add information to the mental model. The listing of perceptual events may be useful for part-task training development around relating perceptual events to the appropriate mental model panel or category. Research on visual scanning in ATC suggests that one frequent source of error may be a failure to use the information contained in these perceptual events to update the mental model contents (see Section V, this report).

Section IV of this report describes in detail the functional interrelationships among the mental model, tasks, task triggers, task subgoals, and perceptual events.

III. EXPERT STRATEGIES ANALYSIS

III. EXPERT STRATEGIES ANALYSIS

Method

Participants

During Phase II, new data were collected on a DYSIM work overload problem. Only experts participated in the work overload problem. This group was made up of 8 controllers with 4 or more years of FPL experience (Mean Age=40.2, S.D.=11.8; Mean Years FPL=8.17, S.D.=6.72).

Procedures

Two analyses were performed as part of this extension to the preliminary strategies identified in Phase I (Human Technology, 1990, pp. 44-54). The first analysis was an extension of the Phase I analysis conducted on the two structured problems of 65% complexity. This analysis involved a comparison of how experts, intermediates, and novice controllers employ cognitive strategies while controlling air traffic. During this second phase, additional data were also collected from a work overload problem presented to experts. The analysis of this problem takes a more detailed look at experts' use of strategies while experiencing high levels of workload.

During the Phase I data collection, the participants were individually presented with two 20-minute DYSIM structured problems of 65% complexity as follows:

- Structured Problem 1: This problem represents a job bottleneck. Three commercial aircraft have been accepted. All are landing in Tulsa and require sequencing and two will need routing. About midpoint in the problem, three more Tulsa arrivals approach the sector, and they will also require sequencing.

- Structured Problem 2: This problem represents a rapid-paced scenario. There are two refuelers that require a frequency change, followed by a Life Guard aircraft requesting higher altitude. There is also a Miami departure that needs radar identification over the Miami VORTAC. At about 15:00 minutes, there are three aircraft landing in Tulsa that require sequencing.

During the current phase of data collection, experts were presented with a 20-minute work overload problem:

> Work Overload Problem: This problem was designed to present about a 125% workload for an individual working without any D-Side assistance. By 7:25 minutes into the problem, there are approximately 11 aircraft in the sector. These aircraft include 2 arrivals from the south going to Tulsa presenting an overtake situation, several arrivals into McAlester, and several departures from Miami. By minute 14:00, there are about 19 planes in the sector. At this point, there are 5 additional arrivals into Tulsa representing a number of ties and requiring substantial sequencing.

Procedures (Continued)

The participants first were given 2 hours to familiarize themselves with Aero Center by working a couple of practice problems, and then they were presented with the work overload problem. They were informed that the problem might become difficult to manage but that they should work the problem as though in an actual control situation. The experimenter did not prompt the participant, but only observed. After the problem was completed, the participant was given a work overload Questionnaire to answer (see Appendix E of this report).

Following a 10-minute break, the work overload scenario the controller had just worked was played back to him. The participant was asked to discuss each control action taken, and, most importantly, why he decided on that action. The participant was asked to talk continually about the situation, being as explicit and detailed as possible in explaining the rationale for his decision in choosing specific actions or strategies. There were also six freeze points during the playback, and the participant was asked to describe what happens over the next minute in the sector by giving the important information on the aircraft, the part of the plan being executed, and the specific tasks and strategies employed.

The work overload problem protocols were transcribed in their entirety. Most participants had difficulty completing the problem, and one participant asked to terminate the exercise after 12 minutes into the problem. The seven complete transcripts were reviewed, and the five that demonstrated the highest degree of performance were selected for coding. The transcripts were coded for the following three types of strategies: planning, monitoring, and workload management. In order to account for all comments, the following three codes were also added in the coding for this problem: Other workload management strategy; Sector or equipment unfamiliarity comment; Procedural or non-strategy-related comment.

Measures And Data Analysis

The goal of this analysis was to isolate and define controller "cognitive-optimizing strategies." These cognitive-optimizing strategies are strategies or heuristics that help the controller execute procedures more efficiently. Strategies should be distinguished from ATC procedures. Controller procedures are those collections of actions specified in the air traffic control handbook, 7110.65F. Strategies are less-well-defined, may include the combination of a number of procedures, are more difficult to verbalize, and are indicative of expertise.

The controller strategies identified in Phase I included both cognitive strategies and control procedures. A review of these strategies revealed that the previously identified control strategies were procedural and behavioral in nature and should not be considered in this extended analysis. With the current focus clearly on cognitive-optimizing strategies, the first objective of this phase was to eliminate the control procedures from that initial listing of strategies. Therefore, a new strategy listing was constructed which resulted in three high-level categories of strategy types: Planning, Monitoring, and Workload Management.

Measures And Data Analysis (Continued)

The new listing of cognitive strategies was then validated and expanded through extensive interviewing of five SME's. These interviews were transcribed (see Appendix C) and were reviewed in order to identify additional strategies. Based on that review, the 22 cognitive strategies from Phase I were expanded to the 40 strategies listed in Table 4. Then, in order to obtain additional validation from experts, a list of those cognitive strategies was presented to five other SME's for rating and in-depth discussion. The SME's were encouraged to discuss each strategy, and also were prompted for related and additional strategies.

Measures And Data Analysis (Continued)

Table 4. List Of Strategy Codes And Their Sources (DYSIM Protocols Or Structured Interviews)

STRATEGY CODE	SOURCE
1.0 Planning Strategies	
Are there conflictions or potential conflictions?	INTERVIEW
Determine aircraft requirements	DYSIM
Determine amount of time available to affect separation once aircraft is in sector	DYSIM
Determine form of separation (e.g., vertical, lateral, or longitudinal separation)	INTERVIEW
Determine how weather and winds will affect the sector	DYSIM
Determine sequence	INTERVIEW
Determine the nature of the overtake	DYSIM
Determine when to implement backup plan	DYSIM
Determine when to start an action	DYSIM
Determine which aircraft to make first (in line)	INTERVIEW
Develop backup plan	INTERVIEW
Develop early primary sector plan	INTERVIEW
Does the aircraft require special attention?	DYSIM
Let speed take effect	INTERVIEW
Prioritize actions	DYSIM
Refine and update primary sector plan or action plan	INTERVIEW
Wait and see	INTERVIEW
What are the aircraft variables including altitude, speed, route, and traffic?	INTERVIEW
What is the aircraft's performance class or characteristics?	DYSIM
2.0 Monitoring Strategies	
Evaluate adjacent sectors	DYSIM
Monitor to start action	DYSIM
Monitor action to completion	DYSIM
Monitor separation	INTERVIEW
Monitor sequencing	INTERVIEW
Monitor to compare strips with PVD data	DYSIM
Monitor to review and update control action plan	DYSIM
Monitor to update primary sector plan or implement backup plan	INTERVIEW
Monitor to vector aircraft	INTERVIEW
Monitor to verify aircraft has reached altitude	DYSIM

Measures And Data Analysis (Continued)

Table 4. List Of Strategy Codes And Their Sources (DYSIM Protocols Or Structured Interviews)
(Continued)

STRATEGY CODE	SOURCE
3.0 Workload Management Strategies	
Are there times of heavy sector traffic and workload?	DYSIM
Descend an aircraft to get the quickest separation	DYSIM
Determine action requiring minimum coordination	DYSIM
Determine how to expedite aircraft through your sector	INTERVIEW
Determine which action results in the lower workload	DYSIM
Determine what to do to eliminate a factor	INTERVIEW
Identify aircraft that are not a factor	DYSIM
Is it efficient to assume early control (reaching out)?	INTERVIEW
Monitor workload	DYSIM
Select action that will require least monitoring	DYSIM
Which action can be completed the quickest?	DYSIM

Measures And Data Analysis (Continued)

Next, the appropriate level of analysis for these strategies had to be determined. Strategies may be divided into two broad categories: heuristics and algorithms. Heuristics are normally those strategies that are described at a general level of detail, while algorithms are step-by-step procedures. The Phase I analysis identified both heuristics and a large number of algorithms. The heuristics include those general strategies that controllers use to help select the appropriate control action.

A total of 320 algorithms or productions (like the one shown in Table 5) were identified in Phase I from the analysis of two structured problems. With the current emphasis on the identification of groupings of strategies to help in training, it was clear that the algorithm level was too detailed and would result in an unmanageable number of strategies. What was needed was a way to subdivide Planning, Monitoring, and Workload Management into about 10 to 20 manageable categories for coding. It was decided to code the strategies at a level neither too specific nor too general, as the research literature demonstrates this so-called "basic level" to be the ideal level of detail for learning and training (see Redding, 1990, for a review). Therefore, 40 strategies were identified that represented the full range of Planning, Monitoring, and Workload Management strategies. This listing provides an identification of groupings of cognitive strategies that can serve as a structure in the training of key cognitive skills in air traffic control. Section XI of this report provides a glossary defining each of the strategies.

These strategies, listed in Table 4, were the basis for the coding of the controller protocols obtained from the DYSIM scenario playback sessions (where controllers described their control actions and reasons for choosing actions and strategies), both for the analysis of the work overload problem and the re-analysis of the data previously collected on the two structured problems. The frequency of the different strategies was analyzed across the problem types and participant groups.

Table 5. Sample Production Developed During Phase I

PRODUCTION

IF ascending twin AC is clear of traffic
AND there are several inbounds
AND ascending AC can be vectored away from inbounds
AND vector can expedite situation

THEN assign requested altitude
AND vector for traffic (away from inbounds)
AND monitor to vector back on course

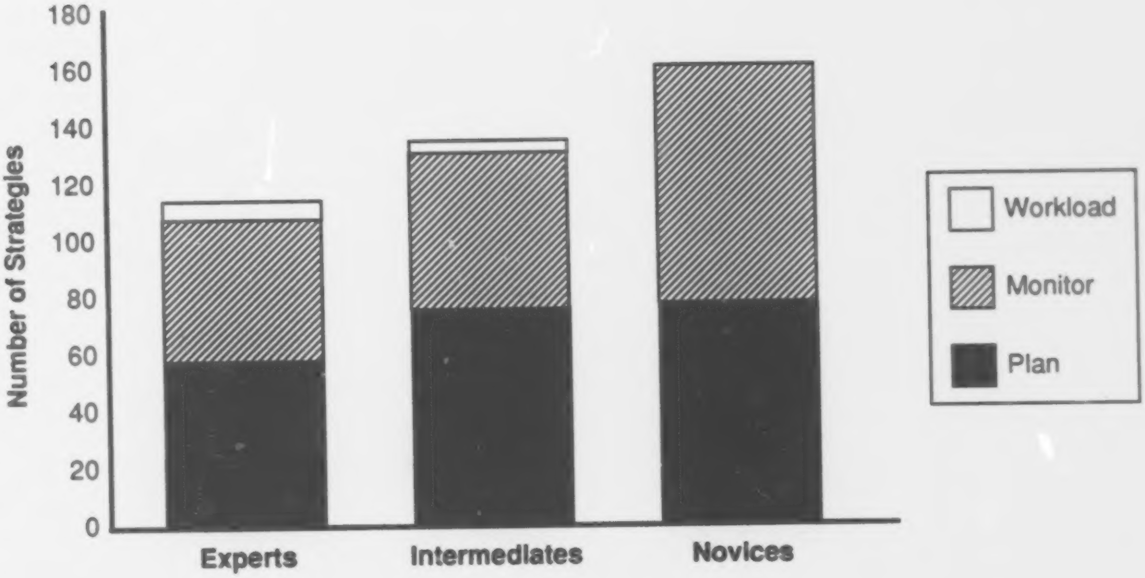
Results

Results Of Expert Strategies Analysis

Results showing the relative usage frequencies of the three strategy categories for each group of participants are presented in Figures 5 and 6. Figure 7 presents these data for both problems combined. Figure 8 presents strategy usage among the experts on the work overload problem (recall that only experts participated in that problem).

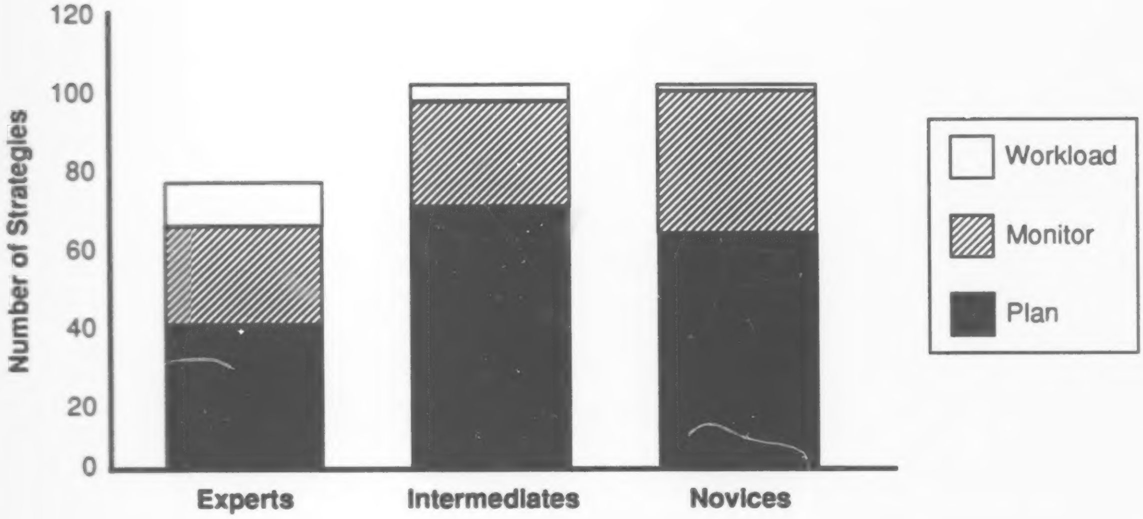
Results Of Expert Strategies Analysis (Continued)

Figure 5. Frequency Of Strategy Usage Across Groups For Structured Problem 1



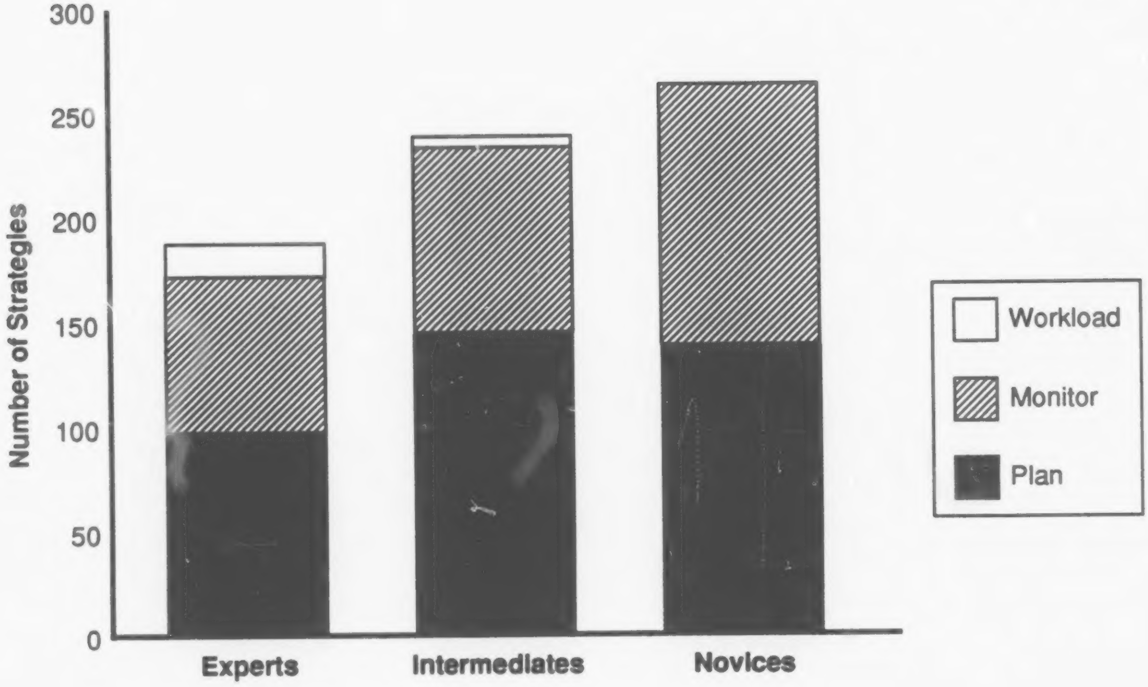
Results Of Expert Strategies Analysis (Continued)

Figure 6. Frequency Of Strategy Usage Across Groups For Structured Problem 2



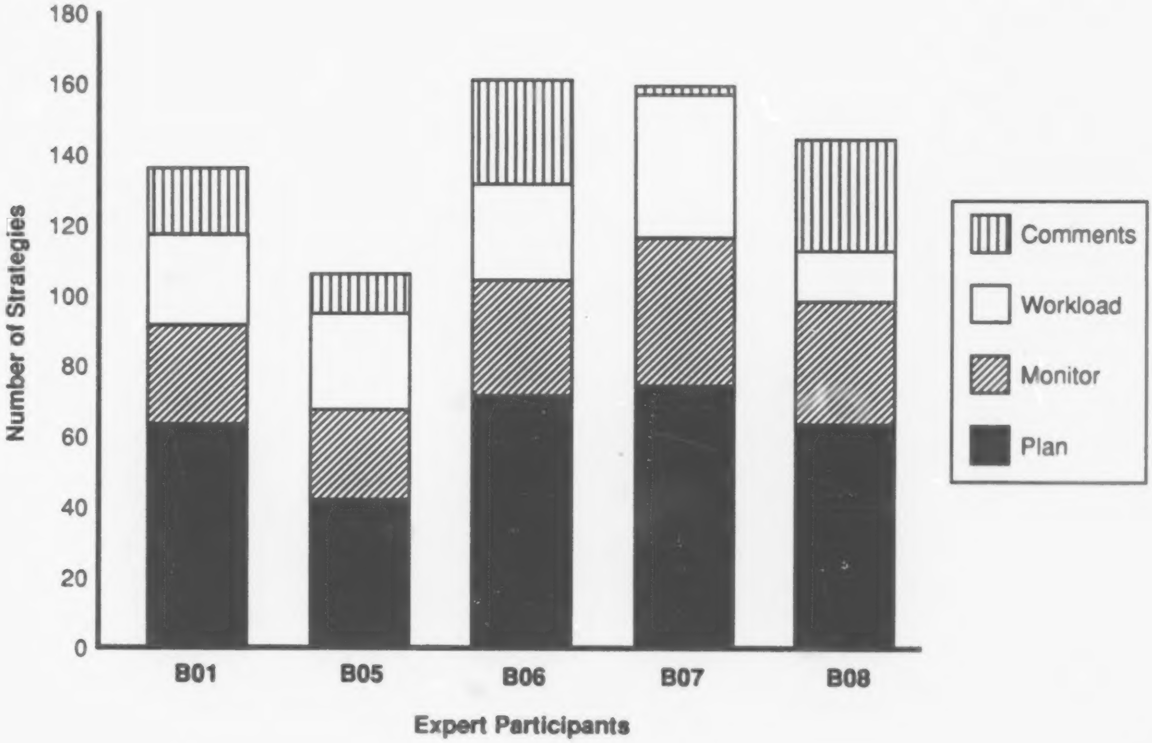
Results Of Expert Strategies Analysis (Continued)

Figure 7. Frequency Of Strategy Usage Across Groups For Both Structured Problems Combined



Results Of Expert Strategies Analysis (Continued)

Figure 8. Strategy And Comment Frequencies For Work Overload Problem



Structured Problems

Several trends are apparent in the results from the structured problems. The experts tend overall to use fewer strategies (only 114) as compared with intermediates (who used 136) and novices (who used 162). A review of the expert and novice protocols shows that experts tend to include more control actions and/or aircraft in their fewer number of strategies. Therefore, experts are potentially more efficient at controlling the same situation by invoking fewer strategies. The view emerging from these different analyses is that experts are better able to organize sector elements into the events or groupings within the Sector Traffic Events panel of the mental model. Even though the experts used fewer instances of strategies, they did use a greater variety of strategies. In Structured Problem 1, for example, the experts used 27 different strategies; the intermediates used 23 and the novices 22. Reason (1987c) argues that expertise is characterized by an elaborated skill-based and rule-based repertoire of behaviors, as experts should have a larger number of strategies. It is reasonable for experts to have a wider repertoire of different strategies that they can invoke when required. Finally, the use of workload management strategies was relatively infrequent compared to the total use of planning and monitoring strategies. This result is consistent with the fact that both structured problems were rated at 65% complexity and, therefore, would not require substantial workload management.

A two-way (Experience level x Problem type) Analysis of Variance (ANOVA) showed a significant effect of experience level upon use of workload management strategies, $F(2,24)=20.39$, $p<.0001$. Post-hoc comparisons showed significant differences between all three participant groups, with experts most frequently using workload management strategies (Mean=2.20; S.D.=1.23) followed by the intermediates (Mean=.90; S.D.=.88). These differences can be seen in Figure 9. A two-way ANOVA also showed a nearly significant effect of experience level upon use of planning strategies, $F(2,24)=3.29$, $p=.055$. There were differences between the expert vs. intermediate/novice groups in their use of planning strategies, but these differences did not quite reach standard significance levels: experts used planning strategies less frequently (Mean=12.20, S.D.=3.43) than did intermediates and novices (Mean=15.50, S.D.=5.08). There were no significant differences across participant groups in the use of monitoring strategies.

A two-way ANOVA was also carried out for each of the strategy types (planning, monitoring, and workload management), to determine whether use of each strategy type varied significantly across problem types or experience level. There was statistically significant variability in use of Planning [$F(1,24) = 5.32$, $p<.05$], Monitoring [$F(1,24) = 21.48$, $p<.001$], and workload management [$F(1,24), = 6.722$, $p<.05$] strategies between the two problem types, indicating that strategy usage varies with context. Across all groups, monitoring strategies were used less frequently on Structured Problem 2 (see Figure 10), $F(1,24) = 38.63$, $p<.0001$. This less frequent usage is probably because Problem 2 imposed a number of time constraints, thus reducing time available for monitoring activities. Control actions had to be taken immediately in this critical, job bottleneck situation.

Structured Problems (Continued)

Figure 9. Interaction Between Experience And Strategy Usage

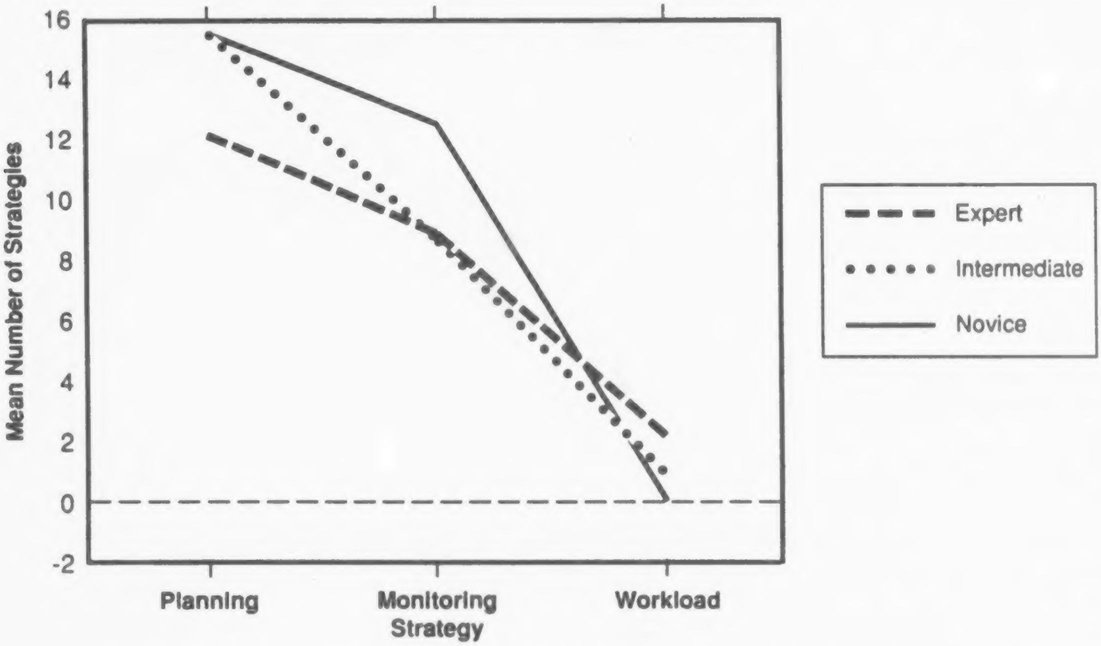
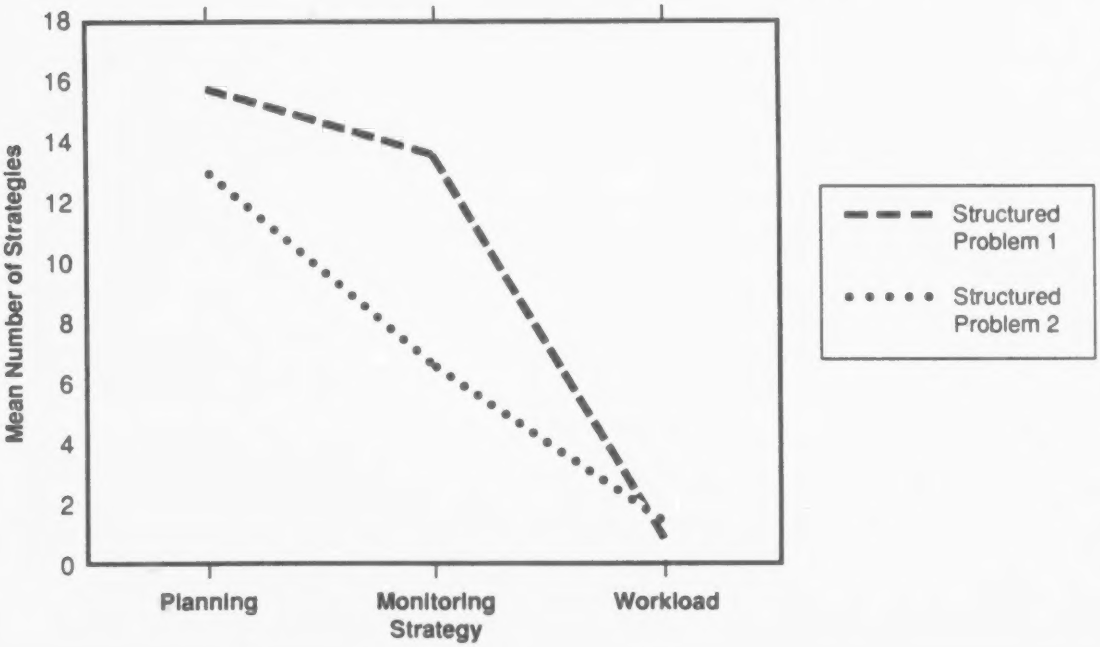


Figure 10. Interaction Between Problem Type And Strategy Usage



Structured Problems (Continued)

A three-way ANOVA was performed to analyze the number of strategies across both problems. The three factors were level of experience (three levels), problem type (two levels), and strategy type (three levels). There were significant main effects for problem type ($F = 21.52$, df = 1,72, $p < .0001$) and strategy type ($F = 1243.92$, df = 2,72, $p < .0001$). Because all two-way interactions were significant, comparisons were made of the main effects. Several interesting patterns of strategy usage emerged between the groups in Structured Problem 1 as compared with Structured Problem 2. On Problem 1, experts used significantly ($p < .05$) fewer planning strategies (Mean=12.0; S.D.=4.06) than intermediates (Mean=16.6; S.D.=2.3) or novices (Mean=18.8; S.D.=4.32). Novices, however, used significantly ($p < .05$) more monitoring strategies (Mean=19.0; S.D.=7.58) than either intermediates (Mean=11.2; S.D.=1.92) or experts (Mean=10.6; S.D.=2.51). On Problem 2, experts (Mean=2.8; S.D.=0.837) and intermediates (Mean=1.4; S.D.=0.894) used significantly ($p < .05$) more workload management strategies than they did on Problem 1 (Mean=1.6; S.D.=1.34; and Mean=.04; S.D.=0.54; respectively).

Recall that Structured Problem 1 imposed a number of time-critical job bottlenecks, thus requiring relatively more short-term planning and relatively less long-term planning. Perhaps experienced controllers used planning and monitoring less frequently with this problem because they readily recognized that it required immediate, reactive controlling. The novices may not have as quickly recognized the control actions that were required under the time pressures; thus, they had to consider what the sector plan should be and monitor the situation in order to determine what was going on. Conversely, Structured Problem 2 represented a series of rapid-paced events, but dispersed throughout the scenario, thus perhaps requiring more long-term planning and strategies aimed at reducing workload as the scenario evolved. This may explain why the experienced groups used more workload management strategies during Problem 2.

In general, then, experts used significantly more workload management strategies, but relatively fewer planning strategies. Their less frequent use of planning strategies may simply reflect the fact that their expertise made it unnecessary to do as much advance planning; their familiarity with similar situations/scenarios meant they already knew more about what the sector plan should be like. Another likely reason for their relative lack of planning is the experts' lack of recent familiarity with Aero Center. This inference highlights the importance of sector-specific knowledge in sector planning.

Structured Problems (Continued)

An examination of the use of specific strategies across groups and problem types revealed several key differences (see Tables 6 through 8). "Monitor separation" is heavily used by all three groups. Both "Identify aircraft that are not a factor" and "Determine how to expedite aircraft through your sector" are used more frequently by experts. "Determine when to start an action," however, is used more frequently by novices as compared with experts. Although these strategies seem to follow similar usage patterns across both problems, there were several other strategies that seem to have more unique patterns dictated by the problem itself.

While there was variability across problem types in patterns of strategy usage, a strong pattern seen overall is that experts did make more use of workload management strategies, specifically by determining how to expedite aircraft through the sector and identifying aircraft that are not a factor (which therefore do not require the same monitoring effort as other aircraft).

Structured Problems (Continued)

Table 6. Expert Strategy Usage Across Both Structured Problems Combined

Frequency	Strategy Category
	Primary Sector Planning
3	Develop early primary sector plan
1	Develop backup plan
	Control Action Planning
19	Refine and update primary sector plan or action plan
10	Are there conflictions or potential conflictions?
9	What are the aircraft variables including altitude, speed, route, and traffic?
9	Determine when to start an action
8	What is the aircraft's performance class or characteristics?
8	Determine aircraft requirements
7	Determine sequence
6	Determine form of separation (e.g., vertical, lateral, or longitudinal separation)
5	Prioritize actions
5	Determine which aircraft to make first (in line)
5	Determine amount of time available to affect separation once aircraft is in sector
4	Let speed take effect
4	Determine how weather and winds will affect the sector
2	Wait and see
1	Evaluate flow control
1	Does the aircraft require special attention?
	Monitoring
43	Monitor separation
10	Monitor sequencing
10	Monitor to vector aircraft
10	Monitor action to completion
3	Monitor to update primary sector plan or implement backup plan
2	Monitor to verify aircraft has reached altitude
1	Monitor to start action
1	Monitor to review and update control action plan

Structured Problems (Continued)

Table 6. Expert Strategy Usage Across Both Structured Problems Combined (Continued)

Frequency	Strategy Category
	Workload Management
12	Identify aircraft that are not a factor
7	Determine how to expedite aircraft through your sector
2	Determine what to do to eliminate a factor
1	Which action can be completed the quickest?
1	Is it efficient to assume early control (reaching out)?

Structured Problems (Continued)

Table 7. Intermediate Strategy Usage
Across Both Structured Problems Combined

Frequency	Strategy Category
	Primary Sector Planning
3	Develop backup plan
1	Develop early primary sector plan
	Control Action Planning
29	Refine and update primary sector plan or action plan
23	Determine when to start an action
18	Are there conflictions or potential conflictions?
16	Determine aircraft requirements
14	Determine form of separation (e.g., vertical, lateral, or longitudinal separation)
10	What are the aircraft variables including altitude, speed, route, and traffic?
10	Determine sequence
7	Determine which aircraft to make first (in line)
6	Determine how weather and winds will affect the sector
5	Let speed take effect
4	Monitor action to completion
3	Prioritize actions
3	Determine amount of time available to affect separation once aircraft is in sector
2	What is the aircraft's performance class or characteristics?
2	Wait and see
1	Determine amount of time available to affect separation once aircraft is in sector
	Monitoring
59	Monitor separation
11	Monitor to vector aircraft
7	Monitor sequencing
3	Monitor to update primary sector plan or implement backup plan
1	Monitor to verify aircraft has reached altitude

Structured Problems (Continued)

Table 7. Intermediate Strategy Usage Across Both Structured Problems Combined (Continued)

Frequency	Strategy Category
	Workload Management
5	Identify aircraft that are not a factor
4	Which action can be completed the quickest?
2	Determine action requiring minimum coordination
1	Is it efficient to assume early control (reaching out)?
1	Determine what to do to eliminate a factor
1	Determine how to expedite aircraft through your sector

Structured Problems (Continued)

Table 8. Novice Strategy Usage
Across Both Structured Problems Combined

Frequency	Strategy Category
	Primary Sector Planning
2	Develop early primary sector plan
1	Develop backup plan
	Control Action Planning
33	Determine when to start an action
22	Refine and update primary sector plan or action plan
21	What are the aircraft variables including altitude, speed, route, and traffic?
16	Determine sequence
13	Wait and see
13	Are there conflictions or potential conflictions?
4	Prioritize actions
4	Determine which aircraft to make first (in line)
4	Determine aircraft requirements
3	Let speed take effect
2	What is the aircraft's performance class or characteristics?
2	Determine amount of time available to affect separation once aircraft is in sector
1	Identify aircraft that are not a factor
1	Determine when to implement backup plan
1	Determine the nature of the overtake
	Monitoring
58	Monitor separation
31	Monitor to vector aircraft
19	Monitor sequencing
9	Monitor to update primary sector plan or implement backup plan
4	Monitor to verify aircraft has reached altitude
4	Monitor action to completion
1	Monitor to start action

Structured Problems (Continued)

Table 8. Novice Strategy Usage Across Both Structured Problems Combined (Continued)

Frequency	Strategy Category
	Workload Management
2	Determine what to do to eliminate a factor
1	Identify aircraft that are not a factor

Work Overload Problem

The purpose of the work overload problem was to obtain data about the usage of workload management strategies among expert controllers. The results are summarized in Figure 8. These five experts referred to an average of 123.6 strategies in solving the 20-minute high-workload problem. In comparing the specific frequencies to those from the structured problems (see Figure 7), it is evident that participants in this problem used a much higher frequency of workload management strategies. In fact, the workload management strategies accounted for about 22% of all the strategies used. This portion is understandable in light of the fact that these data were gathered from a problem that presented about a 125% workload situation.

Analysis of the work overload protocols resulted in the identification of 136 specific instances of 9 different classes of workload management strategies. A detailed listing of one of these classes, "Other workload management strategies," is shown in Table 9. The 26 strategies in this listing are quite detailed, demonstrating that the number of strategies at that level of detail becomes very large. This phenomenon emphasizes the need to arrive at the proper level of detail when presenting strategies to trainees.

Work Overload Problem (Continued)

Table 9. Examples Of Other Workload Management Strategies (Grouped By Expert)

- When under a heavy workload, tell a lower priority requester that you will get back to them (Stand by).
- When under a higher workload, do not accept aircraft from another sector that may be a conflict unless the other sector specifies a plan.
- When under a higher workload, do not accept handoffs.
- The fastest way to get a landing aircraft clear of a conflict is to descend that plane because it will descend faster than anything else and will involve less monitoring.

- Do not answer a request or call if you have higher priority actions or a heavy workload.
- Say "Unable" to a pilot request that is not required when the workload is heavy.
- Terminate a request on a VFR when traffic is building.
- Having the D-Side take on more work as the workload builds.
- Try to keep the speech rate low and steady as more planes come on frequency.
- Request that the adjoining center hand you aircraft in-trail as the workload builds.
- Reduce reliance on strips and their markings as the workload builds.
- Stop taking handoffs from other sectors or approach as the workload becomes too heavy.

- If you have a heavy workload, have departure expect clearance at a point in time when the workload is reduced.
- Do not offer a service if you are experiencing a heavy workload.
- Under conditions of a heavy workload, carefully select your priorities around the key factors.

- Determine that an aircraft will not be a factor for a specified period of time.
- When you have two aircraft that need to be descended, descend the lower performance aircraft.
- Say "Unable" to a pilot request for holding when that area will become congested.
- When under a heavy workload, specify a time at which a potential problem will become a factor.
- Delay taking a handoff until you have time to work with the aircraft.
- When under a heavy workload, if a handoff is not a factor or there is not traffic with the handoff, accept that handoff.
- Determine when there is just one thing that needs to be done to an aircraft.
- Do not answer a request or call if you have higher priority actions or a heavy workload.
- When you have an overtake in a high workload environment, consider speeding up the lead aircraft.

- When under a heavy workload, do not provide a lower priority service if it will increase the workload.
- When under a heavy workload, if a handoff has no traffic, consider accepting that handoff.

Limitations Of The Data

It should be noted that there are some limitations to these analyses of controller strategies. In both the structured problem solving and the work overload problem solving, there was little mention of strategies related to the adjoining sector. This result may be an artifact of using DYSIM problems in Aero Center airspace, because when controllers had a chance to discuss strategies in the validation interviews, there were several comments discussing how they include the adjoining sector in their planning process. The validation interviews thus provided a more complete view of controller strategies.

It is evident that the current listing of strategies is limited to those strategies that have been activated by the three problems. For example, there were substantial differences in expert strategy usage especially when comparing the structured problem solving results with the work overload results, suggesting that the types of strategies elicited depend upon the problem presented. It is not possible to make a good estimate of the total number of strategies needed to successfully manage a sector, but it is probably significantly larger than the number of strategies derived from these protocol analyses.

These analyses identified relatively few primary sector planning strategies. It is possible that a large amount of sector familiarity is required before a usable primary sector plan can be developed. A controller needs to know the normal traffic in a sector before he or she can easily identify the keys to any plan, the abnormals, or those two to five aircraft that cannot be grouped into routine sector events. The sector plan then focuses on the solution of those few abnormals with the rest of the plan made up of the normal sets of procedures. In this view, sector familiarity is essential to the development of viable primary sector plans. Because it is unlikely that specific sectors will be taught early in the training cycle, a reasonable alternative is to provide the trainees with specific tools and techniques so that they can readily learn the key sector characteristics of any sector.

Table 10 presents a preliminary structure for organizing controller strategies.

Limitations Of The Data (Continued)

Table 10. A Preliminary Structure For Controller Strategies

1.0 Planning Strategies

Primary Sector Plan (Pre-planning relating primarily to the planning task)

1.1 Determine key factors (abnormals) in the sector (working with strips and PVD)
  Determine the abnormal situations (key factors)
  Determine if a key factor can be eliminated
  Determine how weather and winds will affect the sector

1.2 Determine sector normal events and decompose
  Categorize sector normal aircraft into groupings (e.g., arrivals and departures)

1.3 Develop backup plan

1.4 Refine and update primary sector plan
    (when new aircraft enter sector and you have time)

1.5 Project to identify factors affecting primary sector plan
  Are there times of heavy sector traffic and workload?

Control Action Plan (Related to specific tasks)

1.6 Determine/revise control action plan for sector events
  Determine the nature of the overtake (if rapid overtake, do not use speed for separation)
  Determine amount of time available to affect separation once aircraft is in sector
    (if less than 2 or 3 minutes, reach out for early control)
  Determine which aircraft to make first (usually the fastest or the lead aircraft)
  Determine when to let speed take effect
    (vector to establish sequence and use speed to maintain it)
    (let speed take effect if you have sufficient space for it to work and a workload that will allow monitoring)
  Determine sequence
    (if the same performance class, use current speeds or position to decide)
    (let those already separated run at speed, and pull the one that does not fit)

1.7 Determine/revise control action plan for aircraft
  What are the aircraft variables including altitude, speed, and route?
  What are an aircraft's requirements?
  Does the aircraft require special attention?
  What is the aircraft's performance class or characteristics and how does that affect action plan (accepting handoff, sequencing)?
  Determine best form of separation
    (go vertical until you have lateral separation)

Limitations Of The Data (Continued)

Table 10. A Preliminary Structure For Controller Strategies
(Continued)

1.0 Planning Strategies (Continued)

1.8 Determine/revise possible actions
  Determine effects of weather/wind on action
  Determine which set of actions is best for own sector and/or adjoining sector
  Determine which set of actions is best for aircraft
  Determine if the workload will permit a specific action plan
  Determine if there is an action that will take care of several situations

1.9 Prioritize and re-prioritize actions (First separation, then orderly flow, then service)
  Are there conflictions or potential conflictions?
  Is there an immediate concern and/or does traffic flow need action?
  If there are several actions with similar priority, which can be done the quickest?
    (Descending a plane may get you the quickest separation)
  Are there any aircraft requests?
  Give landers priority over departures

1.10 Project
  Project to determine the effect of actions on workload
  Project to determine the long-term effects of an action or plan

2.0 Monitoring Strategies (Maintaining The Scan)

2.1 Monitor to update primary sector plan or implement backup plan
  Monitor sector events
  Monitor key factors

2.2 Monitor to review and update control action plan
  Compare with current sector understanding
  Evaluate flow control
  Evaluate adjacent sectors

2.3 Monitor to follow through on control action
  Monitor action to completion
  Monitor to vector back on course
  Monitor separation
  Monitor to verify aircraft has reached altitude
  Monitor sequencing

2.4 Monitor to compare strips with PVD data

2.5 Monitor present and upcoming workload

Limitations Of The Data (Continued)

Table 10. A Preliminary Structure For Controller Strategies
(Continued)

3.0 Workload Management Strategies

3.1 Determine which action results in the lower workload
Determine the action requiring minimum coordination
Sequence to minimize workload (Do you need to coordinate to achieve a specific sequence?)
Select action that will require the least monitoring
Vertical separation may require the least monitoring
Descending an aircraft will get you the quickest separation and reduce monitoring
Route aircraft so that there is minimum impact on other traffic
Clearing for VOR approach involves less work than vectoring for ILS approach
Is it efficient to assume early control (reaching out)?

3.2 Determine most efficient way to communicate control action
(Giving full route clearance and then holding for release can be more efficient than just holding for release, for example)

3.3 Determine if you have time to develop or revise the primary sector plan
Determine whether to pre-plan or develop a control action plan

3.4 Determine how to expedite aircraft through your sector
Expedite handoffs
Speed up aircraft to expedite
Tighten separation to expedite
Reroute to expedite

3.5 Reduce the complexity of your planning/monitoring
Identify aircraft that are not a factor
Determine what to do to eliminate a factor

3.6 Determine if you can interrupt to provide a service
Are there separation problems?
Do you have time to respond to the line (phone) or a request?
The lower the workload, the more service can be provided
Is shortcutting feasible (routing)?
(If low workload, it may be feasible; if heavy workload, you may not have time to determine long-range fixes)
What is the workload of the other team member?

Summary

To summarize the important findings from the analysis of strategy usage, experts tend to use fewer strategies than less-experienced controllers because they appear to include more control actions and aircraft when they implement a strategy. Experts also use a greater variety of different strategies, indicating they have a wider repertoire of strategies. Experts use more workload management strategies, particularly those aimed at identifying aircraft that can be expedited through the sector and those aircraft that are not a factor. These strategies reduce the number of aircraft the controller must actively attend to, thus simplifying the situation. Intermediates also use more workload management strategies than novices, but fewer than the experts, indicating that use of workload management strategies increases over the course of skill acquisition. Experts, however, used fewer planning strategies. Their less frequent use of planning strategies may simply reflect the fact that their expertise made it unnecessary to do as much advanced planning; their general experience and familiarity with similar situations meant they already knew more about what the sector plan should be like. Another likely reason for their relative lack of planning is the experts' lack of recent familiarity with Aero Center, which would highlight the importance of sector-specific knowledge in sector planning.

Another significant finding was that strategy usage varied with context. All groups used fewer monitoring strategies under short-term, time-critical conditions. This finding is understandable given the need to implement immediate control actions in such a situation. Strategy usage is context-specific, there being complex Strategy x Context x Experience interactions. Under short-term, time-critical conditions where there is a job bottleneck with various tasks competing for attention, experienced controllers make less use of planning and monitoring strategies than do novices. This difference is probably because the experts immediately recognize the control actions that must be taken, can immediately get a feel for the situation, and then develop a control plan. Under longer-term conditions where events unfold rapidly throughout the scenario, experienced controllers make greater use of workload management strategies than they do under short-term, time-critical conditions. These findings suggest that patterns of strategy usage within and between groups vary depending upon the particular situation, with a potentially limitless variety of strategy usage patterns. This analysis identified a large number of specific strategies for dealing with specific ATC problem situations. Teaching every one of these detailed strategies would be unmanageable and also of questionable utility.

Because the experts were relatively unfamiliar with Aero Center, the expert-typical strategies that have been identified here will tend to belong to the General Techniques/Strategies category of the mental model. These general strategies will probably be more useful for initial training for several reasons. First, the early phases of training should emphasize general skills and control techniques instead of ones tailored to specific situations or sectors. Second, high-level strategies should be taught prior to more specific strategies. Third, the great variety and the uniqueness of sector-specific strategies suggest that these strategies are best left for sector-specific training in the field.

Summary
(Continued)

The current analysis has successfully identified general trends, and various context-dependent trends as well. It should be noted, however, that this study is just the beginning of exploring the rich variety of strategy usage patterns. The number and complexity of controller strategies point to the need for some structure or organization to make the relatively large amount of material more easily learned, and more easily accessed when needed in real-time controlling. The higher-level strategies presented in this report are just a beginning at strategy specification and organization. Even though controllers make real-time decisions based on a dynamic model of the situation, it is critical that their knowledge in long-term memory be accessed efficiently so that this knowledge can be rapidly integrated into the dynamic portions of the mental model. In the same way that a large number of fixed-wing aircraft (8 pages of them in 7110.65F CHG4) can be grouped into five to seven groupings based on their key performance characteristics, so can most of the controller procedures and strategies be arranged in analogous meaningful groupings within the mental model for rapid trainee access.

This typology of strategies must be organized into an efficient structure to promote ease of retention and to allow for ready access from long-term memory. The mental model and the task decomposition framework provide this organization. Within this framework, specific strategies are implemented during the execution of particular task subgoals. The knowledge of the strategies is contained in the mental model, serving as an organizer of the strategies. The appropriate strategy is accessed from the long-term memory portions of the mental model and used to help carry out the task subgoal.

IV. RELATIONSHIPS AMONG THE CONSTRUCTS

IV. RELATIONSHIPS AMONG THE CONSTRUCTS

Relationships Among Key ATC Constructs

Table 11 illustrates the interrelationship among the key constructs of en route ATC developed in this study: the mental model, task triggers, task subgoals, perceptual events, strategies, and critical cues. Note that each combination of constructs is represented twice, depicting the relationship in both directions: how construct X_1 affects X_2, and how X_2 affects X_1. These interrelationships are discussed in more detail below. This table may be useful for explaining the interrelationship among the components of expertise in ATC. If students are to apply the various models in job performance, an understanding of their functional interrelationships is necessary.

Mental Model

The mental model embodies the knowledge of the situation in the sector and may be thought of as a framework for maintaining situational awareness, so every task would be performed with reference to the current state of the mental model. As the underlying knowledge organization structure, the mental model bears a central relationship to all the other constructs. This model the framework by which controllers acquire, organize, retrieve, and implement domain knowledge, tasks, and strategies, and by which they perceive and evaluate task triggers, perceptual events, and critical cues.

The mental model is made up of eight panels that represent different categories of knowledge needed for the successful control of air traffic. The eight panels have been grouped into three high-level categories that correspond roughly to working memory, long-term memory, and a switching mechanism. The relationship between the mental model categories and these psychological constructs is as follows:

Mental Model Categories		Related Psychological Constructs
Sector Management	-->	Working memory
Conditions	-->	Switching mechanism
Prerequisite Information	-->	Long-term memory

The Sector Management category relates primarily to the situational awareness in the controller's working memory, although information of a more long-term character will be committed to long-term memory and then accessed to working memory when the situation requires it (e.g., see Sarter & Woods, 1991). One of the key functions of the Conditions category is to act as a switching mechanism when the controller is experiencing an abnormal or high workload situation that calls for different procedures and strategies. Finally, the Prerequisite Information category includes the knowledge structures and strategies that the controller must learn in order to control a sector.

Mental Model (Continued)

Table 11. Relationships Among The Constructs

	Mental Model (MM)	Task Triggers	Task Subgoals	Perceptual Events	Strategies	Critical Cues
Critical Cues	Reside in Controller Factors panel				May trigger use of Workload Management strategies	—
Strategies	Reside in Procedures panel, primarily the General Strategies level		Used to execute the task subgoal		—	
Perceptual Events	Allow for situational changes to directly update the MM, independent of tasks	May trigger a task by adding a message to the MM		—		May be part of a critical performance cue
Task Subgoals	Performance of cognitive subgoals adds messages to the MM levels	May trigger a task by adding a message to the MM	—		May affect strategy use by adding a message to Conditions category of MM	Ability to execute subgoals informs critical cues
Task Triggers	Cause the controller to execute the tasks, resulting in MM updating	—	Trigger the execution of the tasks subgoals			Ability to respond to task triggers informs critical cues
Mental Model	—	Contents of the MM provide information needed for triggers		Facilitates awareness of perceptual events	Contents of Conditions category is switching mechanism for strategy use	Contents of MM provide information for critical cues

NOTE: Constructs on the left axis are to be read in relation to those listed across the top axis (i.e., how they affect or inform them). In other words, the top axis represents the dependent variables. Blanks indicate no direct relationship known.

Task Decomposition

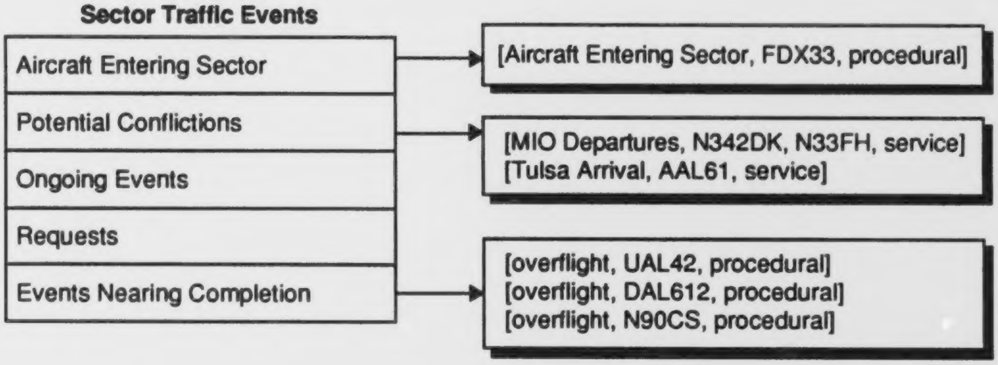
The tasks represent the decomposition of the controller's job into its major components. Each task includes the subgoals that must be carried out to accomplish the task as well as the conditions when the task should be performed (triggers). The tasks include both behavioral and cognitive subgoals. The behavioral subgoals involve performance of control actions; the cognitive subgoals involve interpreting the data obtained about the sector situation, updating situation understanding (by adding, modifying, or deleting information in the mental model), projecting how the situation will evolve, making decisions about how to handle specific events in the sector, and making decisions about how to prioritize tasks.

It is the 2 primary cognitive tasks (Maintain Situation Awareness and Develop and Revise Sector Control Plan) and the cognitive aspects of the other 10 tasks that relate performance to the mental model, because decisions are made with reference to the mental model contents (current situation understanding), and cognitive operations within the tasks update the mental model. Also, the triggers for when to perform each task are based on patterns of information in the mental model. For example, the last subgoal in the task "Receive Handoff" is a cognitive one involving a change to the mental model contents—reclassifying an aircraft from Level 1 within the Sector Traffic Events panel ("aircraft entering the sector") into one or more events such as "a potential confliction." A new event on the Potential Conflictions level of the Sector Traffic Events panel of the mental model then provides one of the triggers for the task Resolve Aircraft Conflict. Attention flows from one task to another because cognitive operations within the tasks update the mental model, which in turn triggers a new task.

Thus, the tasks are linked to the mental model through their triggers and their subgoals. When controllers receive new information, they update their mental model of the evolving situation by incorporating such perceptual information into the Sector Management and/or Conditions categories of their mental model. Actual examples of this model updating, taken from data gathered during validation (see Section II and Appendix A of this report), are presented in Figures 11 through 14. In this manner, the mental model is frequently updated by performing the two primary tasks of Maintain Situation Awareness and Develop and Revise Sector Control Plan. This updating will often result in changes in the various messages (and their parameters) within each of the levels, which may trigger the performance of a task if the messages match one of the defined task triggers. When a message matches a task trigger, the controller performs the specified task.

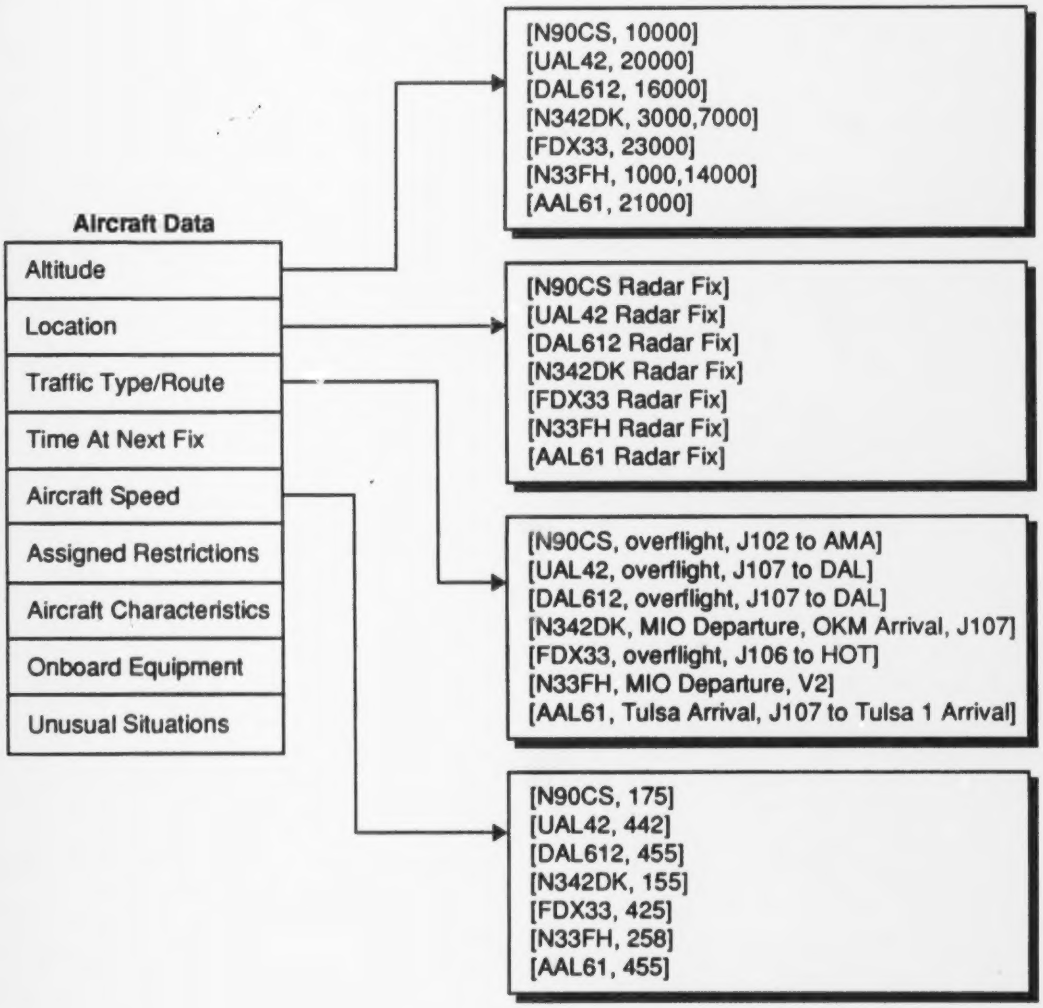
Task Decomposition (Continued)

Figure 11. Contents Of Sector Traffic Events Panel In Validation Timeline (Time 6:30)


Sector Traffic Events
Aircraft Entering Sector
Potential Conflictions
Ongoing Events
Requests
Events Nearing Completion
[Aircraft Entering Sector, FDX33, procedural]
[MIO Departures, N342DK, N33FH, service]
[Tulsa Arrival, AAL61, service]
[overflight, UAL42, procedural]
[overflight, DAL612, procedural]
[overflight, N90CS, procedural]

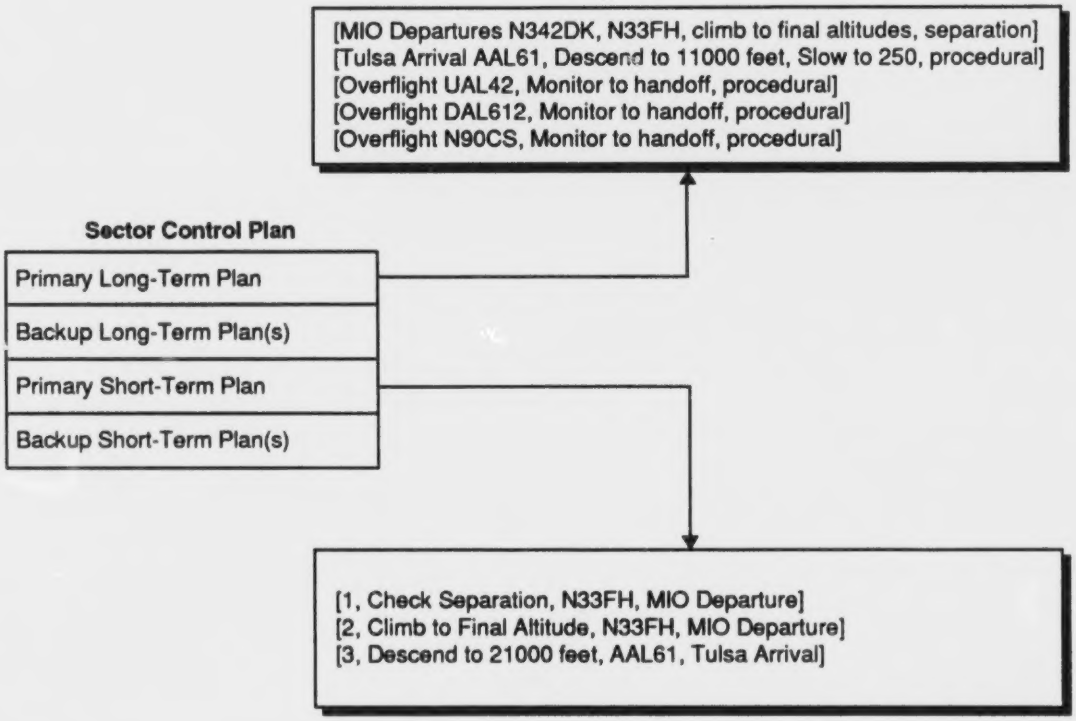
Task Decomposition (Continued)

Figure 12. Contents Of Aircraft Data Panel In Validation Timeline (Time 6:30)


Aircraft Data
Altitude
Location
Traffic Type/Route
Time At Next Fix
Aircraft Speed
Assigned Restrictions
Aircraft Characteristics
Onboard Equipment
Unusual Situations
[N90CS, 10000]
[UAL42, 20000]
[DAL612, 16000]
[N342DK, 3000,7000]
[FDX33, 23000]
[N33FH, 1000,14000]
[AAL61, 21000]
[N90CS Radar Fix]
[UAL42 Radar Fix]
[DAL612 Radar Fix]
[N342DK Radar Fix]
[FDX33 Radar Fix]
[N33FH Radar Fix]
[AAL61 Radar Fix]
[N90CS, overflight, J102 to AMA]
[UAL42, overflight, J107 to DAL]
[DAL612, overflight, J107 to DAL]
[N342DK, MIO Departure, OKM Arrival, J107]
[FDX33, overflight, J106 to HOT]
[N33FH, MIO Departure, V2]
[AAL61, Tulsa Arrival, J107 to Tulsa 1 Arrival]
[N90CS, 175]
[UAL42, 442]
[DAL612, 455]
[N342DK, 155]
[FDX33, 425]
[N33FH, 258]
[AAL61, 455]

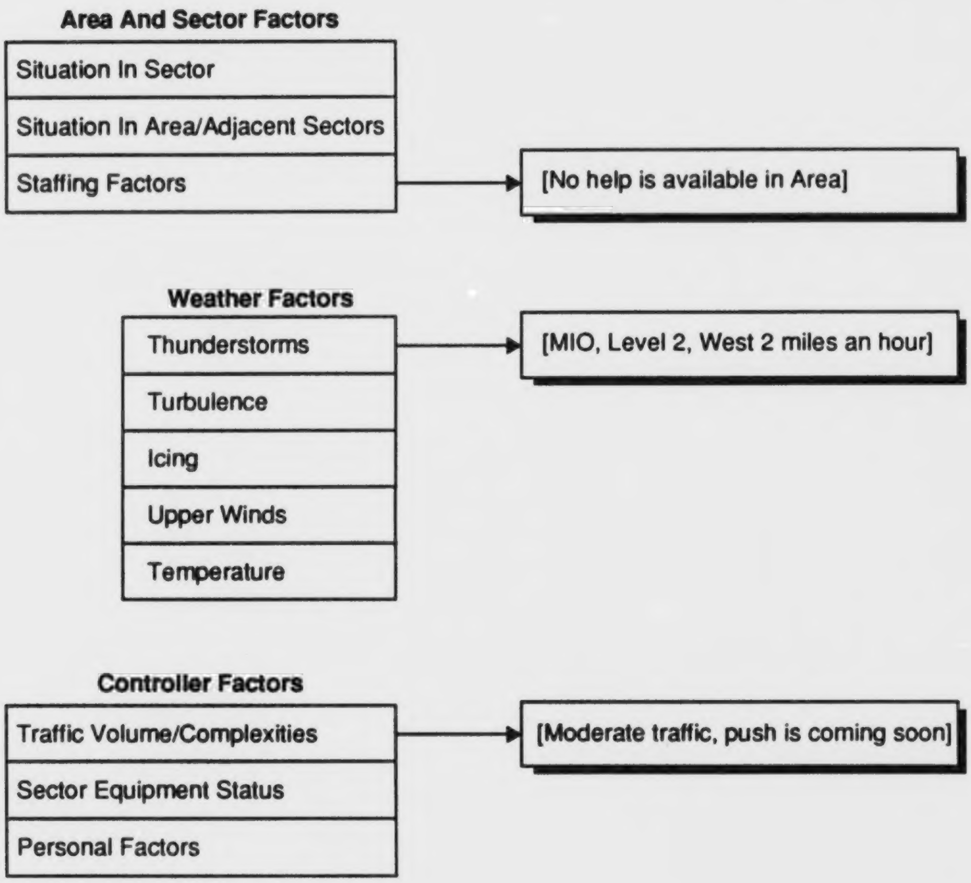
Task Decomposition (Continued)

Figure 13. Contents Of Sector Control Plan Panel In Validation Timeline (Time 6:30)


[MIO Departures N342DK, N33FH, climb to final altitudes, separation]
[Tulsa Arrival AAL61, Descend to 11000 feet, Slow to 250, procedural]
[Overflight UAL42, Monitor to handoff, procedural]
[Overflight DAL612, Monitor to handoff, procedural]
[Overflight N90CS, Monitor to handoff, procedural]
Sector Control Plan
Primary Long-Term Plan
Backup Long-Term Plan(s)
Primary Short-Term Plan
Backup Short-Term Plan(s)
[1, Check Separation, N33FH, MIO Departure]
[2, Climb to Final Altitude, N33FH, MIO Departure]
[3, Descend to 21000 feet, AAL61, Tulsa Arrival]

Task Decomposition (Continued)

Figure 14. Contents Of Area And Sector Factors, Weather Factors, And Controller Factors Panels In Validation Timeline (Time 6:30)


Area And Sector Factors
Situation In Sector
Situation In Area/Adjacent Sectors
Staffing Factors
[No help is available in Area]
Weather Factors
Thunderstorms
[MIO, Level 2, West 2 miles an hour]
Turbulence
Icing
Upper Winds
Temperature
Controller Factors
Traffic Volume/Complexities
[Moderate traffic, push is coming soon]
Sector Equipment Status
Personal Factors

Perceptual Events

Changes in the sector situation (e.g., a request for a clearance) become known to the controller through changes at the workstation (e.g., on the PVD or flight progress strips, from the radio, etc.). These perceptual events allow for data about situational changes to get into the mental model directly, independent of task performance. Once those data are in the mental model, they become part of the information that can be used in task conduct or can trigger a shift of attention to a new task. For example, seeing a data block flash on the PVD directly updates the mental model by adding a message to the Aircraft Entering Sector level of the Sector Traffic Events panel of the mental model. This new message then provides a trigger for the task "Receive Handoff."

Strategies

The strategies are related both to the mental model and to the 12 controller tasks. The mental model organizes conceptual knowledge about the ATC domain, while the 12 tasks embody procedural knowledge about how to accomplish ATC tasks. Strategies are methods for accomplishing tasks. Some strategies are task specific (e.g., strategies for arrival sequencing), while others could be used in many tasks (e.g., workload management strategies). The knowledge about what strategies are useful for specific situations can be thought of as conceptual knowledge, and thus part of the mental model. The mental model Procedures panel includes two levels of knowledge about strategies: General Strategies and Sector-Specific Strategies. The strategies identified in this report are the General Strategies. The primary function of the Conditions panel of the mental model is to act as a switching mechanism for determining when to use different procedures and strategies, as a function of the varying conditions, when strategy alternatives exist for completing a task subgoal.

Strategies also have a relationship to the 12 controller tasks. Knowledge of the strategies resides in the mental model, but use of the strategies is activated by the task subgoals. There is a cycle where tasks are activated by triggers within the mental model. The appropriate subgoals combined with workload conditions then activate the performance strategies most appropriate for the specific situation. This interactive cycle between the mental model and the tasks is constantly repeated as situation awareness and the sector control plan are updated. Therefore, all the tasks have related strategies, but from a cognitive perspective, the key tasks are the two cognitive tasks of Maintaining Situational Awareness and Developing and Revising Sector Control Plan.

Strategies (Continued)

Table 12 shows the relationships among the strategies and the task subgoals, using the following abbreviations:

TASK ABBREVIATIONS

Maintain Situational Awareness (MSA)
Develop And Revise Sector Control Plan (DRSCP)
Resolve Aircraft Conflict (RAC)
Route Aircraft (RA)
Manage Arrivals (MA)
Manage Departures (MD)
Receive Handoff (RH)
Receive Pointout (RP)
Initiate Handoff (IH)
Initiate Pointout (IP)
Issue Advisory (IA)

Strategies (Continued)

Table 12. Relationships Of Strategies To Tasks And Task Subgoals

---

1.0 Planning Strategies

Primary Sector Plan

1.1 Determine key factors (abnormals) in the sector
    LINKED TO TASK = DRSCP
    SUB-STRATEGIES
        Determine the abnormal situations (key factors)
        Determine if a key factor can be eliminated
        Determine how weather and winds will affect the sector

1.2 Determine sector normal events and decompose
    LINKED TO TASK = DRSCP
    SUBGOAL
        Update sector traffic event understanding
    SUB-STRATEGIES
        Categorize sector normal aircraft into groupings

1.3 Develop backup plan
    LINKED TO TASK = DRSCP
    SUBGOALS
        Develop/revise primary and backup long-term plans
        Determine backup strategies

1.4 Refine and update primary sector plan
    LINKED TO TASK = DRSCP
    SUBGOAL
        Develop/revise primary and backup long-term plans

1.5 Project to identify factors affecting primary sector plan
    LINKED TO TASK = DRSCP
    SUBGOAL
        Evaluate aircraft routes with regard to future aircraft separation
    SUB-STRATEGIES
        Determine times of heavy sector traffic and workload

Strategies (Continued)

Table 12. Relationships Of Strategies To Tasks And Task Subgoals
(Continued)

1.0 Planning Strategies (Continued)

Control Action Plan

1.6 Determine/revise control action plan for sector events
- LINKS WITH MENTAL MODEL = DRSCP & MA
- SUBGOALS
  - Determine control actions
  - Derive/revise primary and backup plan for sequencing/slowing/descending
- SUB-STRATEGIES
  - Determine the nature of the overtake
    - If rapid overtake, do not use speed for separation
  - Determine amount of time available to affect separation once aircraft is in sector
    - If less than 4 or 5 minutes, reach out for early control
  - Determine which aircraft to make first
    - Usually make the fastest or the lead aircraft first
  - Determine when to let speed take effect
    - Vector to establish sequence and use speed to maintain it
    - Let speed take effect if you have sufficient space for it to work and a workload that will allow monitoring
  - Determine sequence
    - If the same performance class, use current speeds or position to decide
    - Let those already separated run at speed, and pull the one that does not fit

1.7 Determine/revise control action plan for aircraft(s)
- LINKS WITH MENTAL MODEL = DRSCP, MSA, & RAC
- SUBGOALS
  - Determine control actions
  - Compare aircraft data and current sector understanding
  - Evaluate aircraft route, altitude, time at next fix, goals, and characteristics
- SUB-STRATEGIES
  - What are the aircraft variables including altitude, speed, and route?
  - What are an aircraft's requirements?
  - Does the aircraft require special attention?
  - What are the aircraft's performance class or characteristics and how does that affect action plan (accepting handoff, sequencing)?
  - Determine best form of separation
    - Go vertical until you have lateral separation

Strategies (Continued)

Table 12. Relationships Of Strategies To Tasks And Task Subgoals
(Continued)

1.0 Planning Strategies (Continued)

1.8 Determine/revise possible actions
  LINKS WITH MENTAL MODEL = RA, MA, MD, RH, RP, IH, IP, IA
  SUB-STRATEGIES
    Determine effects of weather/wind on action
    Determine which set of actions is best for own sector and/or adjoining sector
    Determine which set of actions is best for aircraft
    Determine if the workload will permit a specific action plan
    Determine if there is an action that will take care of several situations

1.9 Prioritize and re-prioritize actions
  LINKED TO TASK = DRSCP
  SUBGOAL
    Develop/revise primary and backup short-term plans
  SUB-STRATEGIES
    First separation, then orderly flow, then service
    Are there confliction or potential conflictions?
    Is there an immediate concern and/or does traffic flow need action?
    If there are several actions with similar priority, which can be done the quickest?
      Descending a plane may get you the quickest separation
    Is there a high priority aircraft associated with one of the control actions?
    Are there any aircraft requests?
    Give arrivals priority over departures

1.10 Project
  LINKS WITH MENTAL MODEL = DRSCP & MSA
  SUB-STRATEGIES
    Project to determine the effect of actions on workload
    Project to determine the long-term effects of an action or plan

Strategies (Continued)

Table 12. Relationships Of Strategies To Tasks And Task Subgoals
(Continued)

2.0 Monitoring Strategies (Maintaining The Scan)

2.1 Monitor to update primary sector plan or implement backup plan
  LINKED TO TASK = MSA
  SUBGOALS
    Update sector traffic event understanding
    Update understanding of conditions affecting sector management
  SUB-STRATEGIES
    Monitor sector events
    Monitor key factors

2.2 Monitor to review and update control action plan
  LINKS WITH MENTAL MODEL = DRSCP & MSA
  SUBGOALS
    Update sector traffic event understanding
    Update understanding of conditions affecting sector management
    Develop/revise primary and backup short-term control action plans
  SUB-STRATEGIES
    Compare with current sector understanding
    Evaluate flow control
    Evaluate adjacent sectors

2.3 Monitor to follow through on control action
  LINKS WITH MENTAL MODEL = RAC, RA, MA, IH, and MD
  SUBGOALS
    Monitor aircraft progress to determine whether action is necessary
    Monitor conflict resolution
    Monitor for compliance with rerouting clearance
    Monitor plan execution
    Monitor aircraft and issue clearances to achieve final altitude
  SUB-STRATEGIES
    Monitor action to completion
    Monitor to vector back on course
    Monitor separation
    Monitor to verify aircraft has reached altitude
    Monitor sequencing

2.4 Monitor to compare strips with PVD data
  LINKED TO TASK = MSA

Strategies (Continued)

Table 12. Relationships Of Strategies To Tasks And Task Subgoals
(Continued)

2.0 Monitoring Strategies (Maintaining The Scan) (Continued)

2.5 Monitor present and upcoming workload
- LINKED TO TASK = MSA
- SUBGOAL
  - Evaluate workload and determine the need for assistance

3.0 Workload Management Strategies

3.1 Determine which action results in the lower workload
- LINKED TO TASK = MSA
- SUBGOAL
  - Evaluate workload and determine the need for assistance
- SUB-STRATEGIES
  - Determine the action requiring minimum coordination
  - Sequence to minimize workload
    - Do you need to coordinate to achieve a specific sequence?
  - Select action that will require the least monitoring
  - Vertical separation may require the least monitoring
  - Descending an aircraft will get you the quickest separation and reduce monitoring
  - Route aircraft so that there is minimum impact on other traffic
  - Clearing for VOR approach involves less work than clearing for ILS approach
  - Is it efficient to assume early control (reaching out)?

3.2 Determine most efficient way to communicate control action
- LINKED TO TASK = DRSCP
- SUB-STRATEGY
  - Giving full route clearance and then holding for release can be more efficient than just holding for release

3.3 Determine if you have time to develop or revise the primary sector plan
- LINKED TO TASK = DRSCP
- SUB-STRATEGY
  - Determine whether to pre-plan or develop a control action plan

Strategies (Continued)

Table 12. Relationships Of Strategies To Tasks And Task Subgoals (Continued)

3.0 Workload Management Strategies (Continued)

3.4 Determine how to expedite aircraft through your sector
- LINKED TO TASK = DRSCP
- SUB-STRATEGIES
  - Expedite handoffs
  - Speed up aircraft to expedite
  - Tighten separation to expedite
  - Reroute to expedite

3.5 Reduce the complexity of your planning/monitoring
- LINKED TO TASK = DRSCP
- SUB-STRATEGY
  - Identify aircraft that are not a factor
  - Determine what to do to eliminate a factor

3.6 Determine if you can interrupt to provide a service
- LINKED TO TASK = MSA
- SUBGOAL
  - Evaluate workload and determine the need for assistance
- SUB-STRATEGIES
  - Are there separation problems?
  - Do you have time to respond to the line (phone) or a request
  - The lower the workload, the more service can be provided
  - Is shortcutting feasible (routing)?
    - If low workload, it may be feasible; if heavy workload, you may not have time to determine new routing
  - What is the workload of the other team member?
  - Assess impact of your actions on other team member

Critical Cues Of Work Overload

The critical cues inventory (see Section V of this report) provides a listing of performance and internal state cues relating to work overload. Thus, these cues represent patterns of information on the Controller Factors panel of the mental model. This information, in turn, may trigger switching to one of the related strategies and/or other workload management strategies.

Working Model Of Interrelationships Among Key ATC Constructs

Table 13 provides a working example of how the key constructs in this report are interrelated in actual job performance. The example is based upon an actual ATC scenario.

Working Model Of Interrelationships Among Key ATC Constructs (Continued)

Table 13. Sample Working Model Of Interrelationships Among The Mental Model, Tasks, And Strategies

Description Of Beginning Of Scenario: At this point there are two aircraft engaged in refueling (SPUR12 and SWIFT66), and they are to be handed off to the Memphis Center. Two aircraft (N84CR and LN45T) have departed from MLC and are climbing. Handoffs have been accepted on COA35, an overflight, and N496B, landing at MIO. Finally, N52PB has departed from MIO.

NOTE: The following three lines are selective notations of the comments that the expert participant made while viewing the PVD. Prior to these three comments, the expert discussed all aircraft in the sector based on the strips:

SPUR12 and SWIFT66 the refuel track.

COA35, overflight at 35,000 going to Hot Springs.

FIRST: Get 45T handed off to high altitude.

MENTAL MODEL = AIRCRAFT DATA PANEL:
Altitude Level: [COA35, 350]
Traffic Type/ Route Level: [SPUR12, overflight, going toward Memphis]
[SWIFT66, overflight, going toward Memphis]
[N84CR, departure, MLC to ?]
[LN45T, departure, MLC to ?]
[COA35, overflight, to Hot Springs]
[N496B, arrival, to MIO]
[N52PB, departure, MIO to ?]

TRIGGER = ACCEPT CONTROL OF A SECTOR

(That would trigger the following task)

TASK = MAINTAIN SITUATIONAL AWARENESS
SUBGOAL = EVALUATE AIRCRAFT DATA AND DETERMINE EVENTS IN SECTOR
MENTAL MODEL = SECTOR TRAFFIC EVENTS PANEL:
Ongoing Events Level: [departures climbing from MLC, N84CR and LN45T]
[overflight clear, COA35]
[arrival to M10, N496B]
Events Nearing Completion Level: [refueling track, SPUR12 and SWIFT66]

TRIGGER = NEW EVENT(S) NOT IN PLAN (In Sector Traffic Events Panel)

(That would trigger the following task)

Working Model Of Interrelationships Among Key ATC Constructs (Continued)

Table 13. Sample Working Model Of Interrelationships Among The Mental Model, Tasks, And Strategies
(Continued)

TASK = DEVELOP AND REVISE SECTOR CONTROL PLAN
SUBGOAL = DEVELOP PRIMARY AND BACKUP LONG-TERM PLANS
SUBGOAL = DEVELOP PRIMARY AND BACKUP SHORT-TERM PLANS
MENTAL MODEL = SECTOR CONTROL PLAN PANEL:
Primary Long-Term Plan Level: [Refueling, handoff, to Memphis Center, procedural w/in 5 min]
[departure climbing, handoff to R-30, procedural, priority to Life Guard]

STRATEGY CATEGORY = Identify aircraft that are not a factor
STRATEGY = If you have an overflight with no traffic, it is not a factor and you do not have to determine a control action for the aircraft.

SUBGOAL = DETERMINE CONTROL ACTIONS FOR NEXT 1 - 5 MINUTES

(LN45T, a Life Guard Learjet, needs to be handed off to R-30 and SPUR12 and SWIFT66 need to be handed off)

STRATEGY CATEGORY = PRIORITIZE ACTIONS
STRATEGY = If you have two actions of equal priority, and one aircraft is a Life Guard, then take care of Life Guard first.
MENTAL MODEL =
Primary Short-Term Plan Level: [FIRST: Handoff LN45T to R-30 (high sector]
[SECOND: Handoff SPUR12 to Memphis Center]
[THIRD: Handoff SWIFT66 to Memphis Center]

("FIRST: Get 45T handed off to high altitude.")

5:16 QD-$TUL MIO MLC (alimeter request)
5:19 Got altitudes in...

TRIGGER = ACCEPT CONTROL OF A SECTOR

(That would trigger the following task)

TASK = MAINTAIN SITUATIONAL AWARENESS
SUBGOAL = DETERMINE CONDITIONS IN SECTOR

(Controller notices that altimeter settings have not been entered)

Working Model Of Interrelationships Among Key ATC Constructs (Continued)

Table 13. Sample Working Model Of Interrelationships Among The Mental Model, Tasks, And Strategies
(Continued)

TRIGGER = CHANGES IN CONDITIONS (In Conditions Panel)

(That would trigger the following task)

TASK = REVISE SECTOR CONTROL PLAN
SUBGOAL = REVISE PRIMARY SHORT-TERM PLAN

(That leads to the action of entering altimeter settings)

5:25 LN45T QN-30 (Initiate handoff)
5:41 LN45T: We got 45T handed off to high altitude.

TRIGGER = AIRCRAFT PREPARING TO EXIT AIRSPACE (In Aircraft Data Panel)

(That would trigger the following task)

TASK = INITIATE HANDOFF
SUBGOAL = INITIATE HANDOFF TO RECEIVING CONTROLLER

(That leads to the action of initiating handoff of LN45T)

6:04 SPUR12 and SWIFT66: The SPUR12, they are going through so I will hand them off to Memphis Center.
6:15 SPUR12 QN-M10 (Initiate handoff)

TRIGGER = WHENEVER POSSIBLE

(That would trigger the following task)

TASK = MAINTAIN SITUATIONAL AWARENESS
SUBGOAL = COMPARE AIRCRAFT DATA WITH CURRENT SECTOR SITUATION UNDERSTANDING

(Controller notices that SPUR12 and SWIFT66 are nearing the sector border and checks their variables)

STRATEGY CATEGORY = WHAT ARE THE AIRCRAFT VARIABLES?
STRATEGY = If aircraft are overflights, and they are nearing sector boundary, then hand them off to the appropriate sector.

(That leads to the action of initiating handoff on SPUR12).

V. CRITICAL CUES OF WORK OVERLOAD AND COGNITIVE-PERCEPTUAL CAUSES OF OPERATIONAL ERRORS

V. CRITICAL CUES OF WORK OVERLOAD AND COGNITIVE-PERCEPTUAL CAUSES OF OPERATIONAL ERRORS

Method

Critical Cues Of Work Overload

To determine the relative importance of the warning signs of work overload and to obtain validation for the listing of critical cues of work overload derived from the Phase I analysis (see Human Technology, 1990, p. 78), participants completed a questionnaire (see Appendix E) following the DYSIM Work Overload Problem. The questionnaire asked the controllers to indicate which warning signs they experienced while working the overload problem, and then to rank the warning signs in importance based upon their general experience in the past. Also, controllers were asked to list any additional warning signs, to indicate the relationships between key warning signs and strategies used or actions taken, to identify the strategies they were conscious of using to reduce workload during the overload problem, and to describe how they knew when to ask for assistance. Finally, relevant literature was reviewed to determine factors that have been found to contribute to subjective workload in ATC.

Strategy Usage And Error Rates

The use of strategies was analyzed in relation to error rates on the DYSIM Workload Overload Problem. This analysis was done to determine whether using strategies serves to reduce error rates under heavy workload conditions. An SME was asked to note the errors made by each participant (see Appendix F). Based on that error listing, combined with the participant's comments about his own errors, error frequencies were calculated for each of the following time segments within the problem:

0:00 to 7:25 minutes
7:25 to 9:15 minutes
9:15 to 10:30 minutes
10:30 to 11:30 minutes
11:30 to 14:00 minutes

The error frequencies were analyzed to determine their correlation with a number of other factors including the frequency of usage of various strategy types as well as the frequency of usage of individual strategies.

Strategy Usage And Error Rates (Continued)

The DYSIM videotapes and protocols of the work overload problem also were analyzed to determine whether it was possible to delineate a temporal ordering of work management strategies (i.e., which ones should be used first or last). Due to the large variability among controllers in their use of strategies, it was not possible to specify a temporal ordering of strategies. It appears that there is no general preferential ordering of such strategies among expert controllers. Rather, usage of individual strategies depends upon individual controller preference and the particular air traffic events.

Operational Errors

FAA reports of operational errors for FY 1989 were analyzed. These data were analyzed to determine the types of cognitive and perceptual skills failures leading to operational errors, in order to obtain empirical validation for the anecdotal and case-study evidence that was obtained from the Phase I Critical Incidents Interviews (see Human Technology, 1990, pp. 75-78). First, the summary statistical data contained in the Operational Error/Deviation System (OEDS) data base was examined. Second, analysts obtained the controller personnel reports from the final operational error reports for ARTCC's (46 reports) and conducted a content analysis on each report. From this latter analysis, each report was classified according to the general underlying cognitive operation or perceptual failure that resulted in the error described in the report. The failures, in turn, were related to the types of cognitive process or structures implicated: decisionmaking, mental model structures, perceptual recognition, etc. (Analysts also attempted to perform such a cognitive analysis on all the operational errors listed in the OEDS data base, but this analysis was not possible because that data base did not provide sufficient information about controller thought and decisionmaking.) Third, existing literature on errors in ATC was reviewed to obtain additional support for the findings and conclusions based upon the analysis of FAA OEDS data and the Phase I Critical Incidents results.

Results

Critical Cues Of Work Overload

There was substantial variability in participant responses to the questionnaire, particularly in terms of rank ordering the importance or temporal sequence of critical cues. Because of this variability, as well as the relatively small number of participants completing the questionnaire, it was not possible to develop a precise ordering of the critical cues, either in terms of temporal priority or priority of importance. Nor was it possible to order cues from viewing the problem videotapes or protocols because the cues are subjectively perceived by the controller and thus are not perceived independent of the controller who is working the problem. The questionnaire, however, was useful for verifying the validity of the listing of critical cues obtained in Phase I. The experts verified each of the critical cues by indicating that they had experienced each of them and considered them to be important. Although a precise ordering of the specific cues was not possible, it was clear that a subjective feeling of anxiety was viewed as the most important cue, followed by communication errors.

Participants added two new cues to the list: degradation of D-side functions (e.g., strip-marking and sequencing), and being late with handoffs and pointouts. Participants also added two new workload reduction aids: disregard D-side functions, and eliminate all service-oriented procedures. For the most part, controllers knew to ask for help when the critical cues were activated.

Tables 14 and 15 present a revised critical cue inventory and a listing of representative work reduction aids. (These rules of thumb for reducing workload are to be distinguished from the workload reduction strategies derived from the expert strategy analysis that represent actual controlling strategies, rather than the job-related aids or shortcuts listed here such as disregarding the D-side function.) Within each of the two broad categories (Internal State Cues and Performance Cues), the cues are organized roughly in terms of importance.

Critical Cues Of Work Overload (Continued)

Table 14. Critical Cues Of Work Overload
(Controller Factors Panel)

	Cue Category	Description
Internal State/Subjective Cues:	Anxiety	▪ Feeling uncomfortable ▪ Feeling nervous ▪ Sweaty palms
	Confidence	▪ Decreased self-confidence
	Attention	▪ Development of "tunnel vision" ▪ Over-focusing on problem situation(s)
	Situation Assessment	▪ Similarity to previous occasions of work overload
Performance Cues:	Communication	▪ Failure to listen to, and/or remember, pilot requests and readbacks ▪ Failure to listen to instructions from other controllers ▪ Unsteady voice
	Aircraft Separation	▪ Conflict alerts ▪ Aircraft overtakes
	Skill Degradation	▪ Computer-entry errors ▪ Failure to mark or sequence flight strips ▪ Handoffs and pointouts executed or accepted late

Critical Cues Of Work Overload (Continued)

Table 15. Representative Aids For Reducing Workload

- Request help when work overload cues are triggered
- Reduce or disregard D-side functions
- Simplify and reduce control actions (increase use of workload management strategies)
- Refuse to accept handoffs when becoming too busy
- Plan to have *x* amount of time to communicate, coordinate
- Decrease amount of communication, coordination
- Eliminate all service-oriented procedures
- Decrease or eliminate VFR traffic advisories

Critical Cues Of Work Overload (Continued)

The question arises as to what factors most significantly contribute to workload in ATC. What task-related factors contribute to a sense of work overload, in turn triggering the critical cues just described? Peak traffic levels appear to be the primary task stressor among en route controllers, accounting for 50% of the variance in behaviorally manifested stress levels (Hurst & Rose, 1978a). Frequency of radio communications is the second most significant stressor, accounting for 16% of the variance in behavioral stress levels (Hurst & Rose, 1978a). In a similar study of tower controllers, Hurst and Rose (1978b) found that time spent monitoring was the most significant contributor to behavioral stress, accounting for 15% of the variance, followed by peak traffic, time standing by (i.e., non-task time), time on-frequency, and time off-frequency. The researchers speculated that time spent standing-by may be a stressor due to anticipatory anxiety, noting that Laurig et al. (1971) found that expected planes were a physiological stressor. Interestingly, controllers appear to make fewer errors when the workload is self-paced and flexible, even if there are more aircraft on frequency (Langan-Fox & Empson, 1985). Self-pacing may reduce anticipatory anxiety and stress because it allows the controller to manage his or her own workload and gives the controller greater control over the evolving situation.

Strategy Usage And Error Rates

The five performances of the experts working the work overload problem (see Section III of this Report) were rank-ordered based on the number of controller errors committed between 0:00 and minute 14:00. (Note: Use of the term "error" here generally refers simply to deviations from the ideal, rather than true operational errors.) The average number of errors committed during that time frame was 9.6 (S.D. = 3.07).

By comparing the performance having the least errors with that having the most errors, several patterns are evident. The performance that uses the most workload management strategies achieves the most error-free performance, while the performance with the fewest strategies overall resulted in the greatest number of errors. This negative relationship between number of workload management strategies and number of errors was analyzed in greater detail. As shown in Table 16, correlations were calculated among the following variables:

ERRORS	Number of errors made between 0:00 and 14:00
PLANNING	Number of planning strategies used during the entire problem
MONITOR	Number of monitoring strategies used during the entire problem
WRKLOAD	Number of workload management strategies used during the entire problem
OTHER	Number of other comments made during the entire problem
TOTAL	Total number of strategies used during the entire problem
AGE	The age of the participant
YRS FPL	The number of years of FPL experience

Strategy Usage And Error Rates (Continued)

Table 16. Correlations Between Number Of Errors And Strategy Usage

	ERRORS	PLANNING	MONITOR	WRKLOAD	OTHER	TOTAL	AGE	YRS FPL
ERRORS	1							
PLANNING	-.692	1						
MONITOR	-.912*	.809	1					
WRKLOAD	-.633	.44	.477	1				
OTHER	.483	.01	-.153	-.833	1			
TOTAL	-.671	.963*	.87	.348	.142	1		
AGE	.716	-.058	-.395	-.499	.769	.03	1	
YRS FPL	.743	-.091	-.561	-.221	.432	-.114	.884*	1

* Correlations that were statistically significant at the p < .05 level of confidence.

ERRORS	Number of errors made between 0:00 and 14:00
PLANNING	Number of planning strategies used during the entire problem
MONITOR	Number of monitoring strategies used during the entire problem
WRKLOAD	Number of workload management strategies used during the entire problem
OTHER	Number of other comments made during the entire problem
TOTAL	Total number of strategies used during the entire problem
AGE	The age of the participant
YRS FPL	The number of years of FPL experience

Strategy Usage And Error Rates (Continued)

The negative correlation between ERRORS and MONITOR ($r = -.912$, $p < .05$) is statistically significant while the negative correlations between ERRORS and the other strategy categories are in the expected direction but not statistically significant (due to the very small sample size).

Because the problem represented a work overload situation, another analysis was conducted on the relationship between errors and specific workload management strategies. Table 17 shows the correlations between errors and the use of the following specific workload management strategies:

ERRORS	Number of errors made between 0:00 and 14:00
MON WL	Monitor workload
ELIM FACT	Determine what to do to eliminate a factor
NOT FAC	Identify aircraft that are not a factor
OTHER WL	Other workload management strategies
LOWER WL	Determine which action results in the lower workload
EXPEDITE	Determine how to expedite aircraft through your sector
LEAST M	Select an action that will require the least monitoring

Strategy Usage And Error Rates (Continued)

Table 17. Correlations Between Number Of Errors And Workload Management Strategies

	ERRORS	MON WL	ELIM FA...	NOT FAC...	OTHER WL	LOWER WL	EXPEDITE	LEAST ...
ERRORS	1							
MON WL	.382	1						
ELIM FACT	-.708	-.742	1					
NOT FAC...	-.803	-.091	.598	1				
OTHER WL	-.282	-.9	.444	-.015	1			
LOWER WL	.078	.086	.396	.311	-.441	1		
EXPEDITE	-.797	-.719	.989*	.635	.442	.3	1	
LEAST M...	.357	-.456	-.181	-.397	.73	-.47	-.228	1

* Correlations that were statistically significant at the $p < .05$ level of confidence.

ERRORS	Number of errors made between 0:00 and 14:00
MON WL	Monitor workload
ELIM FACT	Determine what to do to eliminate a factor
NOT FAC	Identify aircraft that are not a factor
OTHER WL	Other workload management strategies
LOWER WL	Determine which action results in the lower workload
EXPEDITE	Determine how to expedite aircraft through your sector
LEAST M	Select an action that will require the least monitoring

Strategy Usage And Error Rates (Continued)

Although none of the individual strategies showed a statistically significant negative correlation with ERRORS, "Determine what to do to eliminate a factor," "Identify aircraft that are not a factor," and "Determine how to expedite aircraft through your sector" are the three strategies most highly related to performance, (i.e., fewer errors) and, consequently, three workload management strategies that require special attention.

Air Traffic Control Operational Errors

Errors by air traffic controllers were responsible for approximately 4.3% of all commercial airline accidents between 1974 and 1983 (Boeing, 1985), and the study of these errors provides a rich source of information about controller prioritizing in critical situations. Errors are the ideal critical situation because they are truly critical, but are more representative of the typical critical incident than the relatively rare near-midair collision. Evaluating performance in critical situations provides an assessment of the ability to problem-solve under novel and/or stressful conditions.

According to the FAA, 99% of all ATC errors were due to human error (FAA, 1990). As reported from the critical incidents interviews (see Human Technology, 1990), most of the errors occurred during the early stages of a controller's career. The most errors were committed by controllers with between 3 and 5 years of experience, while those with less than 1 year's experience committed the second largest number of errors (FAA, 1990).

Data regarding the frequency of controller operational errors suggest that lack of vigilance, due to a failure to Maintain Situation Awareness, may be the primary causal factor in many critical incidents. This conclusion is suggested by the following data.

Most operational errors occurred during traffic levels of average complexity, with no distractions, and with an average of only eight aircraft being controlled. (Traffic complexity is a subjective rating that includes factors such as volume, weather, staffing levels, and emergencies.) In FY 1988, only 19.2% of the errors occurred during high levels of traffic complexity, while 22.9% occurred during average complexity levels and 11% occurred during below-average complexity levels (FAA, 1990). Thus, 33.9% of the errors occurred during average or below-average traffic complexity levels, whereas only 19.2% occurred during above-average levels. (There are no data on complexity for 41% of the incidents.) Controllers were working 10 aircraft or less during 72% of the errors and working more than 10 aircraft only 26.9% of the time (FAA, 1990). During FY 1989, 97.77% of all operational errors occurred while the controller was working the combined R-side and D-side functions and 58.42% occurred while the controller was working a combined sector, thus further suggesting that workload was not heavy. However, 67.69% of the controllers requested assistance upon recognizing that a critical incident had developed or was developing, suggesting that they felt they were unable to handle the situation alone.

Air Traffic Control Operational Errors (Continued)

Previous studies using various methodologies to determine workload have also consistently found that errors are more frequently associated with average or light workload conditions. Stager and Hameluck (1990), using a variety of workload measures, analyzed 301 operating irregularities in the Canadian ATC system and found that about 80% of operational deviations occurred during periods of average or below-average workload. The fact that errors tend to occur most frequently during periods of relatively light workload appears to be the case historically. Fowler (1980) cites several studies from the early 1970's that found this tendency to be the case, and Fowler observes that errors often "are committed by good controllers who have apparently no extraneous factors affecting their behavior at the moment, and yet they might fail to monitor an aircraft plainly visible on their scope" (p. 651).

These data suggest that lack of vigilance in performing the key cognitive task Maintaining Situation Awareness is a frequent source of error. Because errors most frequently occur during normal or even relatively relaxed conditions, active monitoring most likely would avoid the misinterpretation and misuse of data. Controllers attribute failure to interpret radar data properly and/or a misuse of such data as being a causal factor in 33.4% of the errors. Aside from communication and coordination errors that account by far for the greatest number of operational errors (65.66%), misidentification or misuse of PVD data accounts for the greatest number of errors (37.6%), followed by errors in computer entry and flight strip updating (18.8%). Moreover, the activity just before the error was usually a shift break and the controller was usually unaware that a critical situation was developing (FAA, 1990). However, another possible or additional reason for the prevalence of errors following a position break could be simply that the controller must become oriented once again to the sector traffic (Sector Traffic Events and current Aircraft Data), rather than a lack of task vigilance per se.

Thus, results from analysis of the FAA OEDS data base, as well as other research studies, confirm the conclusions of the Phase I Critical Incidents Analysis: inattention, lack of vigilance, and/or misuse of data are the most frequent causes of error (excluding communication errors). All of these factors relate to active monitoring as defined in the task Maintain Situation Awareness. Indeed, a task group convened by FAA in 1987 to study the causes of operational errors and provide recommendations for improvement cited lack of alertness and ineffective PVD scanning as being critical problems contributing to operational errors (FAA, 1987). Training in alertness and visual scanning were two of seven areas recommended to receive special emphasis. "For a variety of reasons, controllers are occasionally missing important...information such as aircraft displayed on PVD's" (p. 40). Ineffective scanning has "resulted in many operational errors and some accidents" (p.40). At least under conditions of high visual taskload, lack of attention (i.e., perhaps actively updating the mental model) rather than decreased visual scanning activity appears to be largely responsible for ineffective scanning particularly when events require considerable processing in order to capture attention (Thackray & Touchstone, 1985; 1988).

Air Traffic Control Operational Errors (Continued)

What specific types of errors do controllers make most frequently? Previous research (e.g., Stager & Hameluck, 1990) has found attentional and decisionmaking factors to be the greatest sources of error, again attesting to the importance of effective monitoring and prioritizing. The most frequent errors were nonrecognition of conflict, inattention, deviation from standard operating procedures, failure to coordinate, and poor judgment, respectively (Stager & Hameluck, 1990). Langen-Fox and Empson (1985) observed the performance of eight British military controllers and obtained their self-reports. They found errors to be related to the amount of time different numbers of aircraft were on frequency (thus, this analysis treated aircraft as events to be dealt with, rather than merely number of aircraft on the screen). The most frequent control errors were the interposition of words or actions due to mentally reversing event sequences (see Norman, 1981) and programmatic errors (e.g., confusion of long-term, short-term, and ongoing plans). The overextension of actions (doing more than necessary or intended) frequently resulted in forgetting about other aircraft under control, while the insertion of inappropriate actions often led to a critical situation. Such action slips may be caused by a failure to monitor one's progress in carrying out the control actions (Reason, 1987c); in other words, maintaining situation awareness.

In the current study, analysis of the controllers' own reports suggests that a mismatch between the controller's expectations regarding a future event and what actually occurred may be responsible for error in as many as 20% of the cases. Such a mismatch most likely would be due to a failure to properly update one's situational awareness within the mental model (i.e., the Sector Traffic Events and Aircraft Data panels, particularly the Route level), and/or a failure to have adequate backup plans for alternative outcomes.

Thus, the two primary cognitive tasks of Maintain Situation Awareness and Revise and Update Sector Control Plan may be implicated frequently in operational errors. For example, the controller expected another center to take a certain action that it did not take, the controller expected the aircraft to take a different routing than it did, the routing was different from what the controller had projected, the D-side expected that aircraft had descended already although the PVD indicated otherwise, etc. Even in cases of error where the aircraft's routing was different than expected because the pilot did not follow the assigned or filed routing, errors nevertheless indicate that the controller was less than diligent in updating his or her situation awareness by monitoring the aircraft and inquiring into the routing.

Finally, the literature on human judgment and decisionmaking was surveyed in order to construct a representative listing of frequent errors in human decisionmaking that are discussed in the literature (see Table 18). The listing focuses on errors or biases relating primarily to planning and prioritizing, and is taken mainly from the work of Reason (1987a; 1987b; 1987c) who reviewed and catalogued biases from the decisionmaking literature, and the seminal work of Kahneman, Slovic, and Tversky (1982) on the use of base rates and biases in decisionmaking. One way to improve the decisionmaking of controllers is to provide explicitly remedial training around these error categories. In other works, ATC errors could be diagnosed in relation to these categories, and training could focus on avoiding these types of errors in future similar ATC situations.

Air Traffic Control Operational Errors (Continued)

Table 18. Common Errors In Planning And Decisionmaking

THE DECISIONMAKER:

1. Will overemphasize importance of situational changes, while that which is unchanged about the situation will be given less attention in decisionmaking.

2. Will give greater emphasis than is warranted to expectations based upon prior experience, in planning for future events.

3. Will fill in missing bits of information based on prior expectancies and old mental models, and thus may later forget that the information was actually missing and/or may confuse their expectations with actual data.

4. Will affirmatively seek confirmatory evidence and fail to assimilate new evidence that conflicts with the plan. This error occurs particularly with more complex, long-term plans.

5. Will be overconfident in assessing the situation, thus failing to consider data that conflict with that assessment.

6. Will underestimate the likelihood of unexpected events, thus planning for fewer contingencies than is desirable.

7. Will overestimate the likelihood of an event occurring if it has occurred that way in the past.

8. Will fail to revise probability estimates frequently enough, typically resulting in overestimation of low probabilities and overestimation of high probabilities of the occurrence of events.

9. Will overestimate the frequency of unusual or recent events or bits of information (due to their salience), thus underestimating the frequency of common, underlying events or information (i.e., "base-rates").

10. Will weigh information in accordance with its vividness and salience, rather than its objective value.

11. Will give greater weight in decisionmaking to information that is most frequently used, most recently used, most readily available, and/or most similar to the present context.

12. Will associate certain action routines or rules of thumb with certain contexts, and may use them automatically in those contexts even when inappropriate.

Air Traffic Control Operational Errors (Continued)

Table 18. Common Errors in Planning and Decisionmaking
(Continued)

THE DECISIONMAKER:

13. Will be biased toward using those plans and strategies that have been successful in the past, rather than using some more appropriate for the current situation.

14. Will categorize and evaluate events or attributes along a single dimension, failing to recognize the independent way in which they vary along a number of dimensions.

15. Will match items, concepts, or events in a one-to-one fashion, even if this matching is invalid.

16. Will judge causality based on perceived surface similarity between cause and effect.

Summary

The following is a summary of the key results from the analysis of errors, critical cues, and relevant literature.

A revised listing of critical cues of work overload was constructed. Although a precise ordering of these cues in terms of importance or temporal priority was not possible, the results clearly indicated that participants viewed anxiety and communication errors as being the most important cues that an overload situation is developing. Additionally, the literature indicates that the primary task-related factors affecting subjective workload are peak traffic levels and the frequency of radio communications. Thus, controllers should be explicitly taught to be alert for these critical cues and task-related factors. Controllers should consider asking for help and using other workload reduction aids when they feel anxious, when traffic levels or events mount, and when the need for communication increases but they are making more communication errors. Time spent monitoring and non-tasking time may also cause stress, the former due to the vigilance required and the later due perhaps to anticipatory anxiety.

Most operational errors are made under moderate to light levels of workload, traffic complexity, and traffic volume, and when the controller is working the combined R-side, D-side functions. Thus, errors tend to occur most often under relatively nonstressful, noncritical, "normal" conditions. This tendency suggests that simply a lack of vigilance in active monitoring, as related to performing the primary cognitive task Maintain Situation Awareness, may be a frequent cause of error. Indeed, controllers themselves cite misidentification or misuse of PVD data as being a frequent cause of error.

An FAA task group has recommended that alertness and scanning receive special emphasis in training. However, research suggests that lack of attention and lack of active processing of information appear to be largely responsible for the misuse or misidentification of data, rather than decreased visual scanning activity. Thus, training programs should emphasize not only vigilance in scanning, but also active processing of the information perceived by performing the subgoals in the Maintain Situation Awareness task, returning to this task as often as possible, and using the information obtained to update and revise the mental model contents. Also, training should emphasize relating perceptual events that occur at the workstation to the appropriate mental model category.

Errors often occur immediately following a shift break, perhaps because the controller failed to orient completely to changes in the sector traffic, suggesting that the Sector Traffic Events panel of the mental model is particularly important not only when starting the shift, but also after a shift break. Past research has successfully related error rates to events, rather than merely to the number of aircraft on the screen. This finding is consistent with the Sector Traffic Events mental model panel that organizes aircraft into event types, and the findings from the strategy analysis that experts include groupings of aircraft in compiled control actions.

Summary
(Continued)

Previous research has also found that action slips (such as computer-entry errors) are a frequent source of error, possibly due also to a failure in attentional checking upon task performance (i.e., monitoring subgoal execution). The two primary cognitive tasks of Maintain Situation Awareness and Revise and Update Sector Control Plan are also implicated in the frequency of mismatches between controller expectations and what actually occurs, as was found in the analysis of controller error reports. Misconceptions about aircraft routing were the most common mismatches found.

Finally, the analysis of performance errors in DYSIM problem solving indicated that the greater the number of strategies used overall, particularly monitoring strategies, the fewer the errors. This finding demonstrates the central importance of monitoring in effective ATC. Three specific workload management strategies were associated with a reduced number of errors: Determine what to do to eliminate a factor, Identify aircraft that are not a factor, and Determine how to expedite aircraft through your sector. The latter two strategies were also found in the strategy usage analysis to be used more frequently by experts. Thus, these strategies deserve particular attention in training.

VI. SUMMARY OF RESULTS

VI. SUMMARY OF RESULTS

Summary Of Phase I And Phase II Results

Table 19 presents a summary of 15 major or high-level conclusions derived from the present Phase II data analysis and model development. Below each general conclusion are listed the lower-level conclusions and results (grouped according to the data collection procedure from which they were derived), leading to the high-level conclusion presented. Note that the conclusions are both in terms of empirical findings and the functional characteristics of the model.

For more specific findings and detailed discussions, refer to the Summary at the end of each primary section of this report. Because this section presents only the most robust high-level conclusions generalizable across the data collection methods, consulting the other sections of this report as well as the findings and conclusions presented in the Phase I report will give a more complete picture of the cognitive analysis process and results. Table 20 lists the key findings of the Phase I research effort.

Table 19. Summary Of Conclusions Based On Results From Each Analysis

Conclusion 1	The **Mental Model** of En Route ATC is the **underlying framework** by which controllers acquire, organize, and retrieve their knowledge.
Data Sources:	
Performance Modeling: Mental Model	▪ An expert mental model was validated. ▪ Controllers referred to the mental model contents in working a scenario. ▪ Patterns of information in the mental model triggered task performance. ▪ Perceptual events (situational changes) are integrated into the mental model.
Performance Modeling: Task Decomposition	▪ All new information acquired through the performance of task subgoals is integrated into the mental model organization. ▪ Task subgoals are performed with reference to the mental model.
Strategy Analysis	▪ The great number and variety of strategies used show that experts must have an organizational framework that allows them to readily access the strategies when necessary.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 1 (Continued)	The **Mental Model** of En Route ATC is the **underlying framework** by which controllers acquire, organize, and retrieve their knowledge.
Data Sources:	
Phase I Paired Paper Problem Solving	▪ Experts take a more comprehensive and organized view of the evolving situation, suggesting the presence of an underlying organizational framework—a mental model.
Errors And Critical Cues	▪ Errors often may be due to a mismatch between expectations based on mental model contents, and what actually occurs.
Other Research	▪ A significant body of research in other domains has shown the central importance of mental models for learning, understanding, and retrieving knowledge (e.g., Gentner & Stevens, 1983), and that this is a key factor differentiating between good and poor performers (e.g., de Jong & Ferguson-Hessler, 1986).

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 2	▪ A current and comprehensive **mental model** is necessary to **Maintain Situation Awareness** and **vice-versa**.
Data Sources:	
Performance Modeling: Mental Model	▪ The expert mental model provides the framework that guides the perception of situational changes. ▪ The most dynamic categories of the mental model, Sector Management and Conditions, represent situational awareness. ▪ The most important panel of the mental model, Sector Traffic Events, represents real-time, moment-by-moment sector awareness.
Performance Modeling: Task Decomposition	▪ Maintain Situation Awareness is the task containing the most subgoals whose operations serve to update the mental model. ▪ The Maintain Situation Awareness task tells the controller what information at the workstation is most important to attend to, thus updating the mental model.
Strategy Analysis	No data from this source.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 2 (Continued)	▪ A current and comprehensive **mental model** is necessary to **Maintain Situation Awareness**, and **vice-versa**.
Data Sources:	
Phase I Paired Paper Problem Solving	No data from this source.
Errors And Critical Cues	▪ Errors often occur when the mental model is not up-to-date, resulting in inadequate situation awareness.
Other Research	▪ An effective mental model is critical in supporting situation awareness (Sarter & Woods, 1991). ▪ One frequent source of error may be a failure to update the mental model when situational changes are perceived on the PVD (e.g., Thackray & Touchstone, 1988).

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 3	**Sector Traffic Events** and **Aircraft Data** are the panels most central to the mental model of En Route ATC.
Data Sources:	
Performance Modeling: Mental Model	▪ These panels represent moment-by-moment situation awareness. ▪ These panels are given priority of importance in the expert mental model. ▪ These two panels were responsible for triggering tasks twice as often as the other five panels combined.
Performance Modeling: Task Decomposition	▪ Controllers most frequently referred to these panels while performing tasks. ▪ Task subgoals correspond to these panels more than any others.
Strategy Analysis	▪ Experts are better able to organize sector elements into groupings under Sector Traffic Events allowing them to include more aircraft in a smaller number of strategies. ▪ Experts more frequently try to determine how to expedite aircraft through the sector congruent with the priorities inherent in the Sector Traffic Events panel.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 3 (Continued)	**Sector Traffic Events** and **Aircraft Data** are the panels most central to the mental model of En Route ATC.
Data Sources:	
Phase I Paired Paper Problem Solving	No data from this source.
Errors And Critical Cues	▪ Errors occur most often following a shift break, perhaps due to a failure to re-orient to Sector Traffic Events and current Aircraft Data.
Other Research	▪ Controllers use individual Aircraft Data to group aircraft into Sector Traffic Events, and experts formulate their planning around events (see Conclusion 4).

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 4	Consideration of aircraft in terms of **events** in sector planning, rather than individual aircraft, is characteristic of expertise.
Data Sources:	
Performance Modeling: Mental Model	▪ The expert mental model includes a separate panel Sector Traffic Events, within which aircraft are classified according to events. This panel is the most important panel in the model.
Performance Modeling: Task Decomposition	▪ The key controller tasks Maintain Situation Awareness and Develop and Revise Sector Control Plan require a determination of events in the sector and reference to the Sector Traffic Events panel. ▪ Other tasks, such as Resolve Aircraft Conflict, also require classification and evaluation of aircraft into event groupings.
Strategy Analysis	▪ Skill progression is characterized by the use of a smaller number of strategies, with experts using the fewest. Experts use fewer strategies because they are able to include more aircraft in the implementation of a strategy indicating that they think about aircraft in terms of related groupings, such as events.

Table 19. Summary Of Conclusions Based On Results From Each Analysis (Continued)

Conclusion 4 (Continued)	Consideration of aircraft in terms of **events** in sector planning, rather than individual aircraft, is characteristic of expertise.
Data Sources:	
Phase I Paired Paper Problem Solving	▪ Experts are more adept at initially perceiving all the important events in the problems.
Errors And Critical Cues	No data from this source.
Other Research	▪ Experts organize aircraft into patterns (Schlager, Means, & Roth, 1990). ▪ Inexperienced controllers may deal with aircraft on an individual basis (Harwood, Roske-Hofstrand, & Murphy, 1991). ▪ Errors have been related to the number of events (Langen-Fox & Empson, 1985). ▪ A significant body of research in other domains shows that the experts group data into meaningful "chunks" (e.g., Chase & Simon, 1973; de Groot, 1965; Egan & Schwartz, 1979), such as an event.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 5	**Altitude, location**, and **route** are the most important **Aircraft Data** factors.
Data Sources:	
Performance Modeling: Mental Model	■ These levels are given priority of importance in the expert mental model. ■ Controllers referred to these levels the most often while performing tasks.
Performance Modeling: Task Decomposition	No data from this source.
Strategy Analysis	No data from this source.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 5 (Continued)	**Altitude, location**, and **route** are the most important **Aircraft Data** factors
Data Sources:	
Phase I Paired Paper Problem Solving	No data from this source.
Errors And Critical Cues	▪ Misconceptions about aircraft routes were the most common cause of errors.
Other Research	▪ Controllers tend to categorize aircraft according to altitude and location (Bisseret, 1971).

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 6	Knowledge of the **sector-specific features** of the airspace is necessary for effective **planning**.
Data Sources:	
Performance Modeling: Mental Model	▪ Controllers included knowledge of the sector airspace features in their planning for sector events, referring to the Sector Airspace panel.
Performance Modeling: Task Decomposition	▪ The task Develop and Revise Sector Control Plan requires reference to the Sector Airspace panel of the mental model.
Strategy Analysis	▪ Experts used few planning strategies, probably because they were unfamiliar with Aero Center airspace.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 6 (Continued)	Knowledge of the **sector-specific features** of the airspace is necessary for effective **planning**.
Data Sources:	
Phase I Paired Paper Problem Solving	No data from this source.
Errors And Critical Cues	▪ Critical incidents often were partly caused by inadequate knowledge of the sector airspace features (Phase I).
Other Research	▪ Controllers estimate that sector-specific knowledge accounts for as much as 50% of all the knowledge required and used on the job (SME Interviews).

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 7	The cognitive task **Maintain Situation Awareness** is central to effective En Route ATC.
Data Sources:	
Performance Modeling: Mental Model	▪ Performance of the Maintain Situation Awareness task is necessary for updating the mental model contents, particularly the Sector Management category, which is the most important category in the model.
Performance Modeling: Task Decomposition	▪ The Maintain Situation Awareness task is returned to whenever possible, so its trigger is always active. ▪ Attention generally flows from this task to the others, then back again. ▪ This task is necessary to perform the other primary task, Develop and Revise Sector Control Plan, with attention often flowing between these two tasks.
Strategy Analysis	No data from this source.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 7 (Continued)	The cognitive task **Maintain Situation Awareness** is central to effective En Route ATC.
Data Sources:	
Phase I Paired Paper Problem Solving	No data from this source.
Errors And Critical Cues	▪ Lack of adequate situation awareness and lack of vigilance are the sources of a large percentage of controller errors. ▪ Misidentification or misuse of PVD data is the cause of about 37% of all errors. ▪ A mismatch between controller expectations and what actually occurs may cause many errors.
Other Research	▪ Ineffective scanning and lack of vigilance account for the most errors and much job inefficiency (see Conclusion 14).

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 8	The cognitive task **Develop and Revise Sector Control Plan** is central to effective En Route ATC.
Data Sources:	
Performance Modeling: Mental Model	▪ The expert mental model includes a separate Sector Control Plan panel, which is one of the most important panels in the model.
Performance Modeling: Task Decomposition	▪ The Develop and Revise Sector Control Plan task is returned to frequently. ▪ Attention generally flows from this task to the others, then back again.
Strategy Analysis	▪ Skill acquisition is characterized by increasing skill in advanced planning, with experts being able to handle solutions with fewer actions and having to implement alternative plans less often (Phases I and II). ▪ Experts develop and effect more high-level plans (Phase I).

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 8 (Continued)	The cognitive task **Develop and Revise Sector Control Plan** is central to effective En Route ATC.
Data Sources:	
Phase I Paired Paper Problem Solving	▪ Skill acquisition is characterized by increasing skill in advanced planning, with experts best able to take a comprehensive view of the scenario and deal with goals in the most efficient fashion.
Errors And Critical Cues	No data from this source.
Other Research	▪ A significant body of research in other domains has shown the central importance of pre-planning in effective problem solving (e.g., Chi, Feltovich, & Glaser, 1981).

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 9	**Short-term planning** differs significantly from **long-term planning** with long-term planning being more characteristic of expertise.
	Data Sources:
Performance Modeling: Mental Model	▪ The expert mental model includes separate categories for short-term and long-term primary and backup plans. ▪ Messages within the long-term plan levels refer mainly to events and major ATC tasks, whereas messages within the short-term plan levels refer mainly to individual aircraft data and specific control actions. ▪ Under heavy workload conditions, controllers referred relatively more often to the short-term plan levels, abandoning long-term planning.
Performance Modeling: Task Decomposition	▪ The task Develop and Revise Sector Control Plan includes separate subgoals for short-term and long-term planning.
Strategy Analysis	▪ Long-term planning is more characteristic of expertise, with experts developing and effecting more long-range, high-level plans and making greater use of speed control (Phase I).

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 9 (Continued)	**Short-term planning** differs significantly from **long-term planning** with long-term planning being more characteristic of expertise.
Data Sources:	
Phase I Paired Paper Problem Solving	No data from this source.
Errors And Critical Cues	No data from this source.
Other Research	▪ Expertise in ATC is characterized by greater use of long-term planning (SME interviews). ▪ Experts may develop more higher-level strategic plans (Hardwood, Roske-Hofstrand, & Murphy, 1991).

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 10	**Strategy usage varies** considerably with context, particularly **workload.**
Data Sources:	
Performance Modeling: Mental Model	▪ The expert mental model includes a separate Conditions category that acts as a switching mechanism by which controllers change or modify strategies based on workload and other conditions such as weather.
Performance Modeling: Task Decomposition	No data from this source.
Strategy Analysis	▪ Experienced controllers use more workload management strategies under heavy workload or time-pressured conditions. ▪ Experts use fewer planning strategies under short-term, time-critical conditions. ▪ Use of specific strategies varies with problem type. ▪ Use of planning strategies may depend on sector familiarity.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 10 (Continued)	**Strategy usage varies** considerably with context, particularly **workload.**
Data Sources:	
Phase I Paired Paper Problem Solving	No data from this source.
Errors And Critical Cues	No data from this source.
Other Research	No data from this source.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 11	Expertise is characterized by knowledge and use of a **great variety of strategies**.
Data Sources:	
Performance Modeling: Mental Model	No data from this source.
Performance Modeling: Task Decomposition	No data from this source.
Strategy Analysis	▪ Skill acquisition is characterized by use of an increasing variety of different strategies, with experts knowing and using more strategy types.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 11 (Continued)	Expertise is characterized by knowledge and use of a **great variety of strategies**.
Data Sources:	
Phase I Paired Paper Problem Solving	▪ Only experts used computer-entry as a workload reduction strategy.
Errors And Critical Cues	No data from this source.
Other Research	▪ Expertise is characterized by an elaborated repertoire of skill-based and rule-based knowledge (Reason, 1987c).

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 12	Use of **workload management** strategies and workload reduction techniques is characteristic of expertise.
Data Sources:	
Performance Modeling: Mental Model	▪ The expert mental model contains a separate Conditions category that acts as a switching mechanism for using workload management strategies under heavy workload conditions.
Performance Modeling: Task Decomposition	No data from this source.
Strategy Analysis	▪ Skill acquisition is characterized by increasing use of workload management strategies, with experts using the most.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 12 (Continued)	Use of **workload management** strategies and workload reduction techniques is characteristic of expertise.
Data Sources:	
Phase I Paired Paper Problem Solving	▪ Experts make greater use of workload reduction methods such as computer entry.
Errors And Critical Cues	▪ When critical cues of work overload are activated, controllers use workload reduction aids.
Other Research	▪ A significant body of research in other domains shows that experts try to reduce their workload.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 13	Use of strategies aimed at simplifying the situation and identifying **aircraft and tasks** that are **irrelevant** is characteristic of expertise.
Data Sources:	
Performance Modeling: Mental Model	▪ Controllers tried to recategorize traffic events into the Events Nearing Completion level of the Sector Traffic Events panel, thus eliminating the aircraft as a factor.
Performance Modeling: Task Decomposition	No data from this source.
Strategy Analysis	▪ Experts use a smaller number of strategies. ▪ Experts take more procedural shortcuts (Phase I). ▪ Skill acquisition is characterized by increasing use of workload management strategies (see Conclusion 12). ▪ Experts make greater use of the specific strategies "Identify aircraft that are not a factor" and "Determine how to expedite aircraft through the sector."

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 13 (Continued)	Use of strategies aimed at simplifying the situation and identifying **aircraft and tasks** that are **irrelevant** is characteristic of expertise.
Data Sources:	
Phase I Paired Paper Problem Solving	▪ Experts make greater use of the simplifying method of computer entry.
Errors And Critical Cues	▪ Experts use workload reduction aids. ▪ Use of the specific strategies "Identify aircraft that are not a factor" and "Determine how to expedite aircraft through the sector" is most closely related to fewer errors. ▪ Experts assign lower priority to ATC-mandated procedures (Phase I structured interviews).
Other Research	▪ A significant body of research in other areas shows that experts try to simplify the problem-solving situation.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 14	**Active monitoring** and task **vigilance** are characteristic of expertise, and failure in these two areas accounts for the most errors and much job inefficiency.
Data Sources:	
Performance Modeling: Mental Model	No data from this source.
Performance Modeling: Task Decomposition	▪ The primary ATC task Maintain Situation Awareness requires active situation monitoring, and this task is returned to whenever possible.
Strategy Analysis	▪ Novices more frequently "wait and see," implying passive, non-goal-directed monitoring.

Table 19. Summary Of Conclusions Based On Results From Each Analysis (Continued)

Conclusion 14 (Continued)	**Active monitoring** and task **vigilance** are characteristic of expertise, and failure in these two areas accounts for the most errors and much job inefficiency.
Data Sources:	
Phase I Paired Paper Problem Solving	▪ Experts make greater use of monitoring methods.
Errors And Critical Cues	▪ Use of monitoring strategies is negatively correlated with errors (i.e., the more monitoring, the fewer errors). ▪ Most operational errors occur during only light to moderate traffic complexity/workload conditions. ▪ In describing critical incidents, controllers report that they were generally unaware that a critical situation was developing. ▪ Misidentification and misuse of PVD data account for about 37% of all errors.
Other Research	▪ Experts assign higher priority to monitoring activities (Phase I, Structured Interviews). ▪ A significant body of research has shown that lack of alertness and lack of vigilance cause many operational errors (e.g., FAA, 1987; Fowler, 1980).

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 15	**Anxiety, communication errors**, and volume of **traffic/traffic events** are the key **indicators of work overload.**
Data Sources:	
Performance Modeling: Mental Model	▪ The expert mental model includes separate levels for Traffic Volume/Complexity, and Personal Factors under the Conditions category, which determines perceived workload.
Performance Modeling: Task Decomposition	No data from this source.
Strategy Analysis	▪ Controllers' use of workload management strategies increased with traffic volume/complexity.

Table 19. Summary Of Conclusions Based On Results From Each Analysis
(Continued)

Conclusion 15 (Continued)	**Anxiety, communication errors,** and volume of **traffic/traffic events** are the key **indicators of work overload.**
Data Sources:	
Phase I Paired Paper Problem Solving	No data from this source.
Errors And Critical Cues	▪ Controllers identified anxiety and communication errors as the primary critical cues of work overload.
Other Research	▪ Traffic levels and frequency of radio communications are primary behavioral stressors in ATC (Hurst & Rose, 1978a, 1978b). ▪ Reducing the number of items through chunking has been found to reduce perceived workload in other domains (e.g., Kahn, Tan, & Beaton, 1990).

Table 20. Summary Of Key Results From The Phase I Data Collection

- In general, experts were better able to think about larger groupings of data, therefore forming cognitive "chunks" of information and increasing their problem-solving efficiency.
- Experts were able to handle solutions with fewer, more "compiled" actions, suggesting better skill in advanced planning and organization of data. The total number of expert actions was generally smaller than those of intermediates and novices in the same situation.
- Experts develop and effect more high-level plans and spend less time reconsidering their plans.
- Experts had fewer cases of implementing backup plans.
- Experts make greater use of workload reduction strategies.
- The experts' pattern of goal selection differs from the patterns exhibited by intermediates and novices.
- Experts do not respond as directly to the need to deal with all potential violations of separation standards immediately.
- When responding to situations that are threatening, experts also simultaneously address other goals.
- Expert controllers take a more comprehensive view of the evolving scenario.
- Expert selection of methods appears to be based upon the mental resources required to execute the action.
- Expert controllers use a well-developed hierarchy of corrective actions or methods to achieve their goals.
- Experts take more procedural shortcuts, being less constrained by typical procedures.
- Novices, as compared to experts and intermediates, tend to assign relatively higher priorities to routine ATC-mandated procedures.
- Novices place relatively less priority on monitoring-type activities than do experienced controllers.
- Under heavy workload conditions, experts appear to place high priority on simplifying their tasks by reducing attention to only necessary activities. Under heavy workload conditions, experts assign much lower priority to calling and coordinating than do both novices and intermediates.

Summary: Essential Features Of ATC Expertise

What are the essential features of expertise in ATC, and how do these features relate to differences between expert and inexperienced controllers? The following summary based upon an integration of the key results from both Phase I (Human Technology, 1990) and Phase II of the cognitive task analysis addresses this question.

Expert controllers possess a rich knowledge base of ATC concepts, principles, procedures, regulations, heuristics, and strategies. Their abilities to organize this vast amount of knowledge are due in large part to an effective underlying mental model. The mental model also helps controllers acquire data about an evolving sector situation, retrieve their knowledge rapidly, and make decisions about how to control a sector. Expertise in ATC, as in other areas, is best characterized as an efficient knowledge structure combined with a rapid retrieval system for applying the knowledge when needed (Ericson & Simon, in press).

The expert mental model of en route ATC has a number of characteristics that make it an efficient organizer of knowledge and a framework for interpreting sector situational changes. The mental model categorizes aircraft in the sector according to important sector traffic events. This grouping of aircraft into event types allows the expert to consider and recall more aircraft, to better formulate a sector plan, and to include a greater number of aircraft in fewer control actions and strategies. The mental model gives priority to aircraft altitude, location, and route in determining the important sector traffic events, thus providing the expert with the knowledge of the key aircraft data elements. The expert mental model includes a component that evaluates conditions relating to the overall sector, weather, and the controller's own internal state and personal factors. It evaluates these conditions and switches to the use of strategies for reducing workload and simplifying the situation under abnormal, stressful, or heavy workload conditions. Thus, experts assess their own limitations and attend to their own internal state cues regarding workload and stress.

Experts try to determine which aircraft will not require controller action and/or which are unimportant for the sector traffic situation, and determine how to expedite aircraft through the sector. Doing this facilitates fitting individual aircraft into event types, with the expert mental model giving priority to transitioning aircraft into an event nearing completion. One way experts do this is to implement a computer entry, such as a handoff, whenever possible. This conserves mental resources, as it is a relatively effortless control action. However, experts use such strategies not only in situations of heavy workload. Rather, they make great use of workload management strategies in general, and are not afraid of taking a procedural shortcut or eliminating an unnecessary activity whenever it is useful to do so.

Experts emphasize the maintenance of active situation awareness. Maintaining situation awareness necessitates active and vigilant visual scanning. In addition, the expert actively evaluates the information perceived and incorporates it into the mental model, which updates the mental model resulting in situation awareness. Thus, expert monitoring activities are goal-directed, rather than passive. The experts don't simply "wait and see," they evaluate. Their scanning patterns are directed at updating each category within the mental model that is relevant for moment-by-moment situation awareness.

Summary: Essential Features Of ATC Expertise (Continued)

Experts take a comprehensive, integrated view of the evolving sector scenario, addressing a variety of goals and situations simultaneously or recursively. Experts then use their situation awareness to develop and revise a long-term sector control plan, and they do so with great facility. Their adeptness at pre-planning is shown by their ability to handle solutions with fewer actions and by the frequency with which they develop high-level strategic plans. Experts also less frequently need to reconsider their original plans or use backup plans than do less experienced controllers. Experts favor efficient long-term planning over reactive, crisis-oriented short-term planning. Although they formulate short-term plans, experts prefer to handle everything with their long-term plans. When short-term planning becomes necessary (typically in heavy workload or critical situations), they use a different strategy for their planning. This strategy consists mainly of implementing immediate control actions and actually doing less planning. Experts consider only the most relevant aircraft data in determining the immediate control actions to take.

The course of skill acquisition involves progressive skill, knowledge, and mental model refinements. These refinements result in successive approximations to the expert-typical characteristics described above.

VII. IMPLICATIONS FOR TRAINING

VII. IMPLICATIONS FOR TRAINING

Introduction

This section summarizes the key training implications in the areas of instructional content, sequencing, media delivery, and training environment. These implications flow from the model of expertise and skill acquisition developed from the Phase I and Phase II data collection and analysis.

How Should Instruction Be Organized?

Air traffic control is a complex job requiring a large amount of knowledge and involving both behavioral (procedural) and cognitive skills. As in other complex cognitive domains, it is not possible to train for all possible situations. Instead, training needs to provide the controller with a framework for acquiring and organizing ATC knowledge. A common theme from the results of these cognitive analyses is the need to include a significant "learning to learn" component in controller training. This component would include a structure for acquiring the large body of complex regulations, strategies, and skills required of the expert controller.

The mental model can provide a structure both for learning and for performance on the job. Teaching this structure to trainees will give them quicker access to expert knowledge because the model provides an organization for the information they are receiving, thus resulting in better organized and more accessible knowledge at an earlier stage in the training process. Practice in thinking about ATC using this mental model will enhance organization and memory chunking (i.e., organizing bits of related information into groups, such as traffic events, thus improving memory efficiency) for all levels of controllers, particularly novices. The mental model provides a framework for acquiring and interpreting data about an evolving sector situation, determining what aspects of the situation are relevant, and making decisions about how to control the sector.

What is needed in training is an emphasis upon contextual factors and overall pattern recognition (e.g., task triggers) for the whole task, and the development of an underlying mental model to serve as a broad cognitive organizer in support of task performance. The mental model and the associated task decomposition provide a framework for categorizing events, for understanding the overall sector situation, and for organizing knowledge and task strategies. This framework entails a shift in organization away from discrete, behavioral tasks to the more global cognitive and perceptual activities and knowledge categories, using the latter as the primary organizer.

How Should Instruction Be Organized? (Continued)

Instruction should emphasize the underlying cognitive strategies, skills, and mental models found to characterize expertise. Students should be taught to think about tasks in terms of the mental model by having them describe situations in terms of the mental model. Training in expert-typical strategies and heuristics should be explicit at points in training where they become relevant, with information provided as to the mental resource costs and relative efficiency of various strategies. Maintaining situation awareness and pre-planning should receive primary emphasis, as these were found to be the primary factors distinguishing expert from non-expert controllers.

Mental model development can be enhanced by organizing training around "problem types," in other words, by structuring portions of training according to the task decomposition. The 12 tasks provide the framework for "teaching by task." The delineation of subgoals allows instructors to explicitly teach subgoals for accomplishing each task and the strategies related to them.

The task triggers provide the focus for training which tasks to perform at which times. Implicit in the triggers is the prioritization scheme for task performance. Thus, in learning the task triggers, trainees will be learning the situational context for task performance and the decisionmaking involved in the prioritization of tasks.

The large number of strategies identified shows the need for a structure in the training of controller cognitive strategies. Otherwise, such a complex set of strategies can overwhelm the trainee. The structure of the mental model with its emphasis on sector events and the links between specific strategies and task subgoals provides a way to group strategies so that they can be learned more quickly and accessed more readily during real-time control.

The following sections provide more detailed recommendations based on the general approach just described. Recommendations are presented for the following categories:

- Instructional Content
    - Mental Model
    - Task Decomposition And Perceptual Events
    - Strategies And Goals
    - Decisionmaking
- Instructional Sequencing
- Instructional Media
- Training Environment

Recommendations For Instructional Content

Mental Model

1. Sector Traffic Events is a separate panel because organization of traffic by events is so important in decisionmaking. Teaching procedures and strategies by event type is an efficient training strategy because it reduces the number of distinct situations that must be learned. Training should emphasize the integration of sector aircraft information into sector-relevant groupings or events so that trainees see the important relationships between related aircraft. Event-based training involves training on how to categorize aircraft into events, and particularly, what aspects of aircraft data are relevant in doing so. Training in recognizing event types is also crucial for recognizing task triggers, because recognizing triggers is in many cases equivalent to recognizing events. Thus, training on analysis of an evolving situation to determine what configuration of aircraft constitutes an event of a particular type facilitates task trigger recognition.

2. Training should be provided in how to re-orient to Sector Traffic Events following a shift break or when coming on duty. Learning to categorize traffic and events in a manner consistent with the Sector Traffic Events panel of the mental model should facilitate this re-orientation.

3. An organizational template should be developed for assisting controllers in communicating and learning sector-specific knowledge and current sector traffic. The template would specify what key questions to ask the controller on duty, and, most importantly, would provide a common point of reference between the relieving controller and the controller on duty.

4. Chunking should be taught to trainees by showing them how to group aircraft into events and how to include a greater number of aircraft in fewer strategies and control actions. The key planning and monitoring strategies are to plan and monitor around sector traffic event patterns. A major function of these strategies is to help trainees develop an efficient grouping of aircraft and sector information. Strategies may be thought of as the "tools" used to coordinate the knowledge and skills of the controller. Thus, the knowledge acquisition process of trainees should be coordinated with the strategies so that the trainees start to think in more manageable chunks.

5. In order to process aircraft data according to events and to think in more manageable chunks, rather than being just told to scan, controllers should be instructed in scanning patterns aimed at perceiving sector events in relation to their sector plan. Scanning patterns that promote the processing of aircraft data according to event types can enhance memory efficiency by organizing data into chunks of related information. Such a scanning strategy may also reduce subjective workload (Kahn, Tan, and Beaton, 1990).

Recommendations For Instructional Content (Continued)

Mental Model (Continued)

6. When teaching the Aircraft Data panel of the mental model, emphasis should be given to the Altitude, Location, and Route levels; and trainees should be taught that this information is particularly important in short-term planning and critical situations.

7. Including a Sector Control Plan panel is useful as a training tool because it highlights the importance of planning. Once the trainee has learned how to handle each event type alone, it is necessary to learn how to handle a sector with events occurring simultaneously. At this point, planning should be introduced. Planning for the sector as a whole should integrate and prioritize the plans for dealing with each separate event.

8. The differences between short-term and long-term planning should be explicitly pointed out, with differential training provided in both. Differences between the subgoals for short-term vs. long-term planning within the Develop and Revise Sector Control Plan task and between characteristics of the Short-Term Plan and Long-Term Plan levels of the mental model should be emphasized. Most importantly, trainees should be taught that short-term planning forces the controller to concentrate only on salient facts needed to separate aircraft, such as altitude, location, route, and speed. Long-term planning requires a comprehensive awareness of the conditions affecting traffic in the sector, and the mental model provides the framework to maintain such a comprehensive situational awareness. Trainees should also be taught to monitor the time spent in short-term versus long-term planning: expert en route controllers spend less time in short-term "reactive" planning because of their highly developed sector awareness and knowledge base of strategies.

9. The implication of the Personal Factors level in the Controller Factors panel is that stress/workload self-assessment is a skill that should be trained explicitly. Trainees should be taught to gauge Staffing Factors and Traffic Volume/Complexity in relation to their own capabilities.

Task Decomposition And Perceptual Events

10. To facilitate mental model development, training should be reorganized around "problem types" (de Jong & Ferguson-Hessler, 1986). Thus, a portion of the training should be structured around the 12 ATC tasks. Training on recognition of the task triggers is particularly important. Recognizing the conditions for task performance is as important as knowing how to perform each task. Rapid and automatic recognition of such triggers is critical because they specify the tasks and accompanying operations that the controller should be accomplishing at any particular point in task evolution.

Recommendations For Instructional Content (Continued)

Task Decomposition And Perceptual Events (Continued)

11. Part-task training should be provided for each task trigger. Trainees should be given repeated practice over a compressed time period in recognizing and identifying task triggers. This training should include practice in trigger recognition and in recognizing the relationships between mental model components (panels), task triggers, and tasks.
12. Part-task training should be provided for each perceptual event, to include training in perceptual event recognition and in recognizing the relationships between mental model components (panels), perceptual events, and scanning techniques.

13. Training should be provided in scanning techniques most effective for perceiving and identifying the important aspects of perceptual events. Not all information in a full data block, for example, is equally important at all times. The mental model provides a framework for identifying the important information at any one time.

14. For each subgoal within the tasks, training should explicitly demonstrate the representative range of appropriate strategies for implementing the subgoal and should then show the differences in the strategies' effects, under varying conditions.

15. The two primary cognitive tasks (those containing the most cognitive subgoals), Maintain Situation Awareness and Develop and Revise Sector Control Plan, are also the two tasks in which experts are the most superior to novices. These tasks should receive primary and continued emphasis throughout training, and they should be taught and practiced in terms of supporting the performance of the other 10 tasks and providing updating for the mental model contents. The other 10 tasks involve both behavioral and cognitive subgoals. By emphasizing the cognitive subgoals within each of the tasks, and their relationship to the behavioral subgoals, training can concentrate on effectively integrating the cognitive operations into the procedural sequences for task performance.

16. The central importance of the cognitive task Maintain Situation Awareness has important training implications. This task should be emphasized throughout training, because it supports all the most critical aspects of expertise in en route ATC: maintaining an effective mental model, active monitoring, and effective scanning and information processing. The relationship of this task's subgoals to various mental model components should also be emphasized, because subgoal implementation updates the mental model. One way to promote effective performance of this task is to assess each trainee's performance while working simulation problems. The situation awareness global assessment technique (SAGAT) (Endsley, 1988; 1989) could be used to assess situation awareness of the scenario. In ATC, for instance, trainees would be asked questions to determine whether their mental model contents are accurate, current, and complete for the scenario in question.

Recommendations For Instructional Content (Continued)

Task Decomposition And Perceptual Events (Continued)

17. Task vigilance and goal-directed scanning and situation monitoring should receive primary emphasis. Their importance could be illustrated by periodically showing how critical incidents in the past (e.g., re-creations from the FAA OEDS reports) could have been avoided through effective monitoring and vigilance. Trainees should be taught monitoring and scanning activities as they relate to each of the task subgoals within the Maintain Situation Awareness task and the mental model contents. Use of monitoring strategies should be emphasized in instruction. One method would be to provide explicit instruction in effective monitoring techniques for each mental model level or panel, and also to emphasize the relative importance of updating each level or panel as a function of varying conditions.

Strategies And Goals

18. Much of current training deals with ATC procedures and, to some extent, techniques for carrying out the procedures. However, expert cognitive strategies can also be codified and taught. Including cognitive strategies in the mental model provides a way to integrate strategy training into a training program organized around the mental model structure.

19. The strategies should be taught in groupings congruent with the mental model. Knowledge in the Procedures panel of the mental model is divided into sector-specific and sector-independent knowledge, and the strategies have also been decomposed into general and sector-specific groupings. This distinction becomes significant in relation to the training of controllers. From a training perspective, it may not be so important that trainees be taught the full range of specific strategies, but rather that they develop a structure into which they can integrate sector-specific strategies that they learn on the job. This report has identified a preliminary organizational structure for the strategies, which can be integrated into the mental model.

20. Explicit training should be provided in recognizing varying workload levels and relating this awareness to selection and use of workload management strategies, and the selection of methods and strategies based on the mental resources they require. The Conditions panel of the mental model provides the framework for doing this, with the critical cue inventory and methods priorities listing (Phase I) providing the heuristics for determining workload and proper resource allocation, respectively.

Recommendations For Instructional Content (Continued)

Strategies And Goals (Continued)

21. Trainees need to know that dealing with potential separation violations is of critical importance, but that focusing exclusively on potential violations may prevent taking actions that would reduce workload. Specific training on prioritization of goals and on the mental resource costs of various methods should be part of the curriculum. One goal of training should be to develop trainee skills in situation monitoring, identifying problems, and setting goals to solve them. The instructor would try to elicit clear goals statements during problem evolution, so that methods can be selected to meet the goal, instead of goals being driven by the trainees' limited repertoire of methods. Trainees should be taught to take a comprehensive view of sector and area, anticipate future events as part of planning, and look for ways to reduce workload and inconvenience to both controller and aircraft.

22. The use of workload management strategies should be emphasized, particularly under heavy workload conditions. Special attention in training should be given to these specific strategies to emphasize their importance: Determine what to do to eliminate a factor, Identify aircraft that are not a factor, and Determine how to expedite aircraft through your sector.

23. Explicit instruction should focus on methods for simplifying the situation, including how to recognize unimportant situations or aircraft, how and when to take procedural shortcuts, and when to use various workload management strategies and workload reduction aids.

Decisionmaking

24. Systematic teaching of the judgment processes and heuristics underlying the application of strategies is missing in the current training process. In the on-the-job training (OJT) environment, a trainee may see a controller use a specific technique, but may not fully understand the conditions and reasons for applying that technique. Consequently, the trainee is likely to apply that same strategy in what appears to be a similar situation, and the strategy may not work because some key condition or conditions were missing. Thus, training should be explicit regarding the "what, when, how, and why" of strategy usage. Additionally, the strategies themselves should be made as explicit as possible.

25. Training should be provided in recognizing decisionmaking biases and knowing how to avoid them. Computer-based instruction could be developed that would present series of situations in which the trainee must make judgments. The situations would be those that would be likely to reveal decisionmaking biases on the part of the controller. The lessons then would provide feedback, including recommendations for how to avoid those biases revealed in the trainee's performance.

Recommendations For Instructional Content (Continued)

Decisionmaking (Continued)

26. The nature of ATC suggests that training around critical incidents should be an integral part of the curriculum. To a large extent, expertise in air traffic control is the ability to effectively manage undesirable or difficult situations. Systematic training should address representative critical incidents, because they are the difficult situations that cause problems for controllers in the operational environment, and because the development of expertise requires an ability to deal with difficult and unusual situations, not just the routine. An FAA task group report concluded that controllers may have "insufficient practice in assessing unusual situations" (FAA, 1987, p. 43). Based on operational error patterns, critical incidents training would appear to be most useful during developmental training, with refresher training during at least the first 5 years of FPL experience.

27. Stager and Hameluck (1990) point out that controllers probably follow rule-based behavior most of the time. As the term implies, rule-based problem solving is based upon familiar strategies, rules, and procedures rather than lower-level behavioral skills or higher-level problem solving such as constructing new theories or testing hypotheses. Rule-based errors typically are what Reason (1987c) terms "strong but wrong." They occur when the individual applies a strategy that typically works in the given situation but that, for whatever reason, may be inefficient in the current situation, or when a person transposes strategies or applies the wrong one. Thus, controller rule-based errors could be reduced by providing remedial and refresher training in procedural knowledge and strategy usage.

Recommendations For Instructional Sequencing

1. Training sequencing should promote development of an effective mental model. In traditional behavioral approaches to training, there is a strong emphasis on building skills in a sequence roughly parallel to Bloom's taxonomy of objectives (Bloom, 1956): knowledges are taught first, to support procedures, which support more critical judgmental and analytical skills. The assumption is that the trainee cannot succeed in the higher level skills without thorough factual and procedural knowledge to support performance. A cognitive approach, however, emphasizes the development of an effective, well-elaborated mental model of the task. In each stage of learning, the mental model guides and organizes learning activities. The mental model tends to emphasize analytical rules and efficient conceptual organization upon which to build skills and knowledge. Because the mental model is an organizer of factual and procedural knowledge, and because the construction of the mental model is at the center of all training activities, the mental model should be taught first and elaborated throughout the course of training. Procedural knowledge is added in increments, and performance exercises are introduced to develop skills, supporting model refinements. Extension and refinement of one's mental model include knowledge and skills to cover unique and critical procedures, exceptions based on weather, emergencies, equipment failures, etc.

Recommendations For Instructional Sequencing (Continued)

2. Effective training does not necessarily always mean teaching novices to model their performance after an expert. Rather, the issue is how best to teach toward expertise through a series of iterative model-building exercises (Redding, 1990). During the course of learning, mental model refinements may contain certain inaccuracies that may actually be helpful initially in learning because they simplify a complex concept. (One preliminary study does suggest that novice controllers may have mental models of ATC that differ from those of experts (Harwood, Roske-Hofstrand, & Murphy, 1991.) For example, novices may classify aircraft into different types of events than would an expert. At this stage, however, what's important is that they learn how to think about aircraft in terms of events. Later, they will learn which event types are most important. Similarly, novices may have to revise their long-term plans with some frequency. It may be beneficial for them to do so in order to learn planning techniques, even though expertise is characterized by having to reconsider plans less frequently.

3. What may be required is a basic decisionmaking training program that permits the student to acquire proficiencies for the explicit, rule-based portions of the decision domain, followed by a problem-generating practice environment (probably computer-based simulations) in which the student acquires advanced decisionmaking skills through exposure to ascending levels of situational complexity (Ryder, Beckschi, Redding, & Edwards, 1988).

4. Currently, some trainees know a great deal about controlling airplanes, but they are not able to assemble that knowledge in such a way that they can take timely actions. Strategies must be taught in such a way that they can be easily accessed at key points in the control process. Therefore, in the early phases of controller training, learning individual strategies may be less important than developing the Prerequisite Information category to efficiently store and access those structures.

5. Strategies should be taught in related groups congruent with the mental model, but practiced in situations where they are used with the appropriate subgoal(s). It is advisable to train knowledge of individual strategies first so they become integrated with the long-term memory component (i.e., Prerequisite Information panels) of the mental model. Once that has been established, then practice should be provided so that the trainee can efficiently integrate the strategy in the performance of the task. Because any strategy may be used with a variety of different task subgoals, it is more efficient for learning to organize and teach the strategies in the context of the mental model and then allow trainees to practice using the strategies with the appropriate task goals.

6. Training should be sequenced so that trainees can practice workload management strategies under conditions of light to moderate workload so that they can gain experience that can eventually be utilized under heavy workload conditions. Thus, the trainees should be allowed to master the key aspects of workload management strategies before they then try to apply them in more demanding environments.

Recommendations For Instructional Sequencing (Continued)

7. Sequencing for task trigger training should involve extended, time-compressed practice recognizing clear situations first, in which relationships between the incoming data and traffic events are consistent and clear. This initial practice should be followed by practice in situations in which trigger recognition and classification are progressively less clear-cut. Training should also be sequenced in a way that will allow the trainees to practice first on individual task types such as sequencing sets of arrivals or accepting handoffs, and the associated strategies. This initial training would be followed by training that combines several task types such as arrivals combined with departures.

8. Instruction should first present and teach only the most relevant stimulus patterns and knowledge categories. This approach has been found to facilitate the development of automaticity, skilled behavior, and situation awareness skills in complex environments (e.g., Kass, Herschler, & Companion, 1990). Only after the development of effective monitoring and scanning patterns, and situation awareness, should the complexity characteristics of the true ATC environment be completely introduced.

9. Instruction should be organized in such a way that small chunks of related knowledge and skills are taught, followed by simulation-based instruction and practice. Otherwise, controllers will not learn how to apply what they have been taught. Learning application of knowledge only after the completion of all classroom instruction can make it difficult for students to integrate the knowledge with real-time controlling. The approach recommended, "problem-based training" (see Barrows & Tamblyn, 1980), is one in which actual problems provide the context for learning the basic knowledge.

Recommendations For Instructional Media

1. The real-time, dynamic nature of ATC suggests the central importance of simulator training as early as possible in instruction. The mental model and the task decomposition do not imply specific kinds of hardware or equipment. It is quite possible to train many of the more abstract aspects of the models described herein with a trained instructor or textbook. However, detailed training in skills related to timing, task and attention switching, and control usage will require accurate simulations of the work environment, with high levels of system availability for all trainees. Advanced levels of cognitive skills training will require computer simulations that provide a high level of fidelity to actual ATC controlling and problem scenarios.

Recommendations For Instructional Media (Continued)

2. Computer-based training modules would be helpful in permitting the students to acquire proficiencies in the explicit, rule-based portions of various decision domains, followed by a problem-generating practice environment in which the students can tune and refine their skills through exposure to ascending levels of situational complexity. Such scenarios could represent typical incidents, but a representative sampling of critical or unusual incidents should also be included, in order to teach problem-solving flexibility, enhance self-awareness, and help controllers further refine and extend their skills. An intelligent tutoring or decision support system could be developed in which instruction in ATC is organized around the mental model and task triggers. At appropriate points in the simulation, such a system could include decision aids and prompts about recognizing task triggers and which categories to reference to in the mental model. The system could also prompt trainees to engage in pre-planning, to formulate higher-level plans, to perform task subgoals, to monitor, and to attend to other developing problems. The trainee would be provided with explicit feedback, and instruction could be tailored to the trainee's level of skill development, with prompts faded out as the trainee gains proficiency.

3. Training should provide continuous feedback and an environment for "guided exploration." A recognized advantage of computer-based simulations is the ability to provide instant and continuous feedback in a nonthreatening manner, and to provide the ideal practice environment for exploration, experimentation, and skill tuning. Tutorial systems can give neutral feedback to trainees and provide the trainees with the opportunity to experiment with the environment in a way that threatens neither the trainee nor the public. They also provide an opportunity for trainees to obtain objective evaluations of their skills, and to experiment in developing varied decisionmaking skills and heuristics.

Recommendations For Training Environment

1. Currently, a large portion of ATC training involves OJT, in which trainees work live traffic while being coached and monitored by an instructor. Knowledge transfer between instructor and trainee in this type of training is the result of informal and somewhat subjective processes, and depends largely on the instructor's attitudes, ability to articulate ATC knowledge, and other variables. Thus, while some OJT instructors may currently teach the cognitive aspects of ATC (e.g., strategies, mental model), OJT is largely an uncontrolled process that can lead to great variability in the quality of cognitive training that trainees receive. The cognitive approach to ATC training will improve the standardization of teaching practices in which instructors must explicitly teach cognitive aspects of ATC, thus providing trainees with a richer and more consistent training program.

Recommendations For Training Environment (Continued)

2. Training (for both trainees and instructors) should include explicit training in metacognitive skills—i.e., "training to learn." Training must show controllers how to focus on cognitive processes and see ways to improve them. A review by Pressley and Levin (1983) revealed that a general principle contained in the performance evaluation literature was that "learning strategies" were more likely to be retained and used if trainees had a positive attitude about their usefulness.

3. Training should directly teach and evaluate trainees' skills, such as the following:

   - Strategies for acquiring, organizing, and retrieving the large bodies of reference knowledge that support expert performance:

     - Organizing information, strategies, and procedures in terms of the mental model.

     - Organizing job components according to the 12 tasks and their subgoals.

   - What questions to ask others to help understand the sector and sector traffic events.

   - How to evaluate performance, from the standpoints of assessing workload and recognizing performance deterioration in stressful situations. Instruction around the mental model should improve self-evaluative skills. One study found that training in underlying rules, for example, resulted in an increase in knowledge of one's own capabilities (Fisk & Gallini, 1989).

4. Flexibility in problem solving should be taught by encouraging active trainee participation, questioning, and experimentation. Trainees should understand that different problem situations will likely require adaptability and modification of prior mental models and heuristics. To facilitate this understanding, trainees must be encouraged to practice their skills and strategies in multiple contexts and ranges of complexity. Training should demonstrate the range of possible solutions to problems and provide trainees with incentives to experiment with different solutions. To do this, the training environment must foster the development of a positive concept of successful controlling. It is easy to develop a picture of en route air traffic control as a negative work environment, where the only things that happen are bad, and the controller's principal goal is to avoid reportable errors. This attitude decreases trainee motivation to experiment.

5. Trainees should be taught why heuristics and strategies are important, why they are being taught, and how they can be applied to the job tasks. Training that teaches cognitive skills, but not their application or importance, is largely ineffectual in facilitating transfer (Redding, 1990).

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IX. GLOSSARY OF TERMS AND ACRONYMS

IX. GLOSSARY OF TERMS AND ACRONYMS

Algorithm:	A specific sequence of steps for solving a problem.
ANOVA (Analysis of Variance):	A statistical test used to determine whether a difference among groups is significant.
ATC Procedures:	The formal control methods and procedures of air traffic control specified in Handbook 7110.65F and other FAA orders.
Automaticity:	The ability to perform a task fast, effortlessly, and without conscious attention. Developed after repeated practice in a consistent underlying context, and/or with consistency between specific stimuli and the responses to them.
Basic Level:	The level at which concepts are most naturally thought about, being neither too specific nor too general, thereby conveying the most relevant information (e.g., collie - dog - animal).
Chunking:	Grouping bits of related data into clusters of information ("chunks"). Chunking increases memory capacity and improves organization, because human short-term memory is limited to between five and nine chunks of information.
COGNET:	A framework for modeling human-computer interaction and decisionmaking in complex real-world environments (COGnitive NETwork Of Tasks).
Cognition:	Thought, perception, and memory.
Cognitive Task Analysis:	The set of procedures employed in this research effort to analyze the mental models, knowledge, and skills required to control airplanes.
Conflictions:	Existing or pending violations of separation standards between aircraft requiring immediate controller attention.
Construct Validity:	The extent to which a model or theory actually reflects the psychological phenomenon it describes.

IX. GLOSSARY OF TERMS AND ACRONYMS
(Continued)

Control Action:	The specific behavior that the controller uses to control aircraft in the sector.
Control Action Plan:	A short-term or real-time plan for immediate sector control actions. This type of plan is to be distinguished from the Primary Sector Plan both in content and in how it is formulated.
Controller Factors:	The cognitive and subjective factors that combine to influence the controller's subjective workload.
Data-Driven:	Driven by the perception of events that must be dealt with.
Domain:	A subject-matter area (e.g., air traffic control).
DYSIM (Dynamic Simulator):	A simulator used in training controllers, which provides simulated real-time scenarios of air traffic.
Event:	A high-level construct representing an important control situation involving one or more aircraft.
Expert Controllers:	The groups of participants used in this cognitive task analysis with the highest level of experience. Expert controllers may be divided into two groups: 1) Supervisors, and 2) other FPL's with 4 or more years of FPL experience.
Goal-Driven:	Driven by the controller's goals.
Heuristic:	A rule of thumb or general strategy. As such, it is more general than an algorithm.
Intermediate Controllers:	The group of participants used in this cognitive task analysis with less than 1 year of FPL experience.
LTM (Long-Term Memory):	Retention occurs when information is transferred from STM (Short-Term Memory) to LTM, where it is stored in the form of schemas, scripts, and mental models. Unlike STM, LTM is not limited in the amount of information it can store.

IX. GLOSSARY OF TERMS AND ACRONYMS
(Continued)

Maintain Situation Awareness:	Ensuring a complete understanding of current and projected aircraft positions, events, and conditions in the sector.
Mental Model:	A dynamic knowledge structure that underlies and supports reasoning about ATC problems.
Mental Model Category:	A high-level grouping of related panels in the mental model.
Mental Model Level:	A subdivision of a panel within the mental model.
Mental Model Panel:	An aspect or module of the ATC knowledge structure or mental model.
Messages:	The specific data elements within the levels of the mental model.
Method:	A way of accomplishing a task subgoal. Similar to a strategy, but more specific.
Novice Controllers:	The group of developmental controllers used in this cognitive task analysis.
Part-Task Training:	Training around particular, important components of an overall job.
Perceptual Events:	Situational changes, such as a flashing data block, that occur unrelated to the performance of a task.
Predictive Validity:	The extent to which a model or theory is able to predict actual job behavior or performance.
Prerequisite Knowledge:	Knowledge of the sector, procedures, strategies, and techniques that should have been learned prior to taking over a sector.
Primary Sector Plan:	A controller's overall plan for a sector covering the next 20 to 30 minutes.

IX. GLOSSARY OF TERMS AND ACRONYMS
(Continued)

Prioritization:	One of the primary controller functions wherein the controller determines which action needs to be performed next, or which event needs to be attended to next.
Productions:	Productions are models of human decisionmaking about specific events that are represented as condition/consequent rules (e.g., If ... then ... statements).
Projecting:	A strategy used by controllers to predict the key events in a sector in the next 20 to 30 minutes.
Protocol Analysis:	The analysis of protocols or verbal reports through the process of coding.
Protocols:	The verbal reports of participants, generally as they are in the process of solving a problem or performing a task.
Sector-Specific:	Those procedures, strategies, or knowledge structures that pertain to a specific sector.
Situation Awareness:	A current, updated, comprehensive, readily accessible mental model.
SME (Subject-Matter Expert):	An expert controller, used to assist the researcher in understanding, analyzing, and interpreting the data and/or the nature of the ATC job.
STM (Short-Term Memory):	Also called working memory, because it stores information currently being used. Has a capacity for holding five to nine chunks of data at any one time, and items not actively rehearsed are lost within about 30 seconds.
Strategy:	The heuristic or technique used by controllers to optimize the performance of certain tasks.
Structured Problem Solving:	The DYSIM-based problem-solving exercises conducted as part of this cognitive task analysis.

IX. GLOSSARY OF TERMS AND ACRONYMS
(Continued)

Switching Mechanism:	A set of high-level rules that help select the proper strategies.
Task:	A unit of goal-directed behavior.
Task Capture:	When one task overrides another due to an urgent change in the situation.
Task Subgoals:	The steps that must be performed to complete the task.
Task Subordination:	When a task cannot be completed without interrupting it first to perform another task.
Task Suspension:	When a task cannot be completed until some other event occurs.
Task Trigger:	Situational conditions (represented as patterns of information in the mental model) that indicate a task needs to be performed.
Task Vigilance:	Maintaining attention on a task.
Transcript:	The written record of the audio or video protocol.

IX. GLOSSARY OF TERMS AND ACRONYMS

(Continued)

Acronyms Used In This Report

AC	Aircraft
AD	Aircraft Data
ANOVA	Analysis of Variance
APREQ	Approval Request
ARTCC	Air Route Traffic Control Center
ASF	Area and Sector Factors
ATC	Air Traffic Control
CF	Controller Factors
COGNET	Cognitive Network of Tasks
DRSCP	Develop and Revise Sector Control Plan
DYSIM	Dynamic Simulator
FAA	Federal Aviation Administration
FPL	Full Performance Level
FPS	Flight Progress Strip
FSS	Flight Service Station
IA	Issue Advisory
IFR	Instrument Flight Rules
IH	Initiate Handoff
ILS	Instrument Landing System
IP	Initiate Pointout
LOA	Letter of Agreement
MA	Manage Arrivals
MD	Manage Departures
MIO	Miami, Oklahoma
MM	Mental Model
MOA	Military Operations Area
MOCA	Minimum Obstruction Clearance Altitude
MSA	Maintain Situation Awareness
MSAW	Minimum Safe Altitude Warning
MVA	Minimum Vectoring Altitude
NAVAID	Navigation Aid
OEDS	Operational Error/Deviation System
OJT	On-the-Job Training
P	Procedures
PVD	Plan View Display
RA	Route Aircraft
RAC	Resolve Aircraft Conflict
RH	Receive Handoff
RP	Receive Pointout
SA	Sector Airspace
SAGAT	Situation Awareness Global Assessment Technique

IX. GLOSSARY OF TERMS AND ACRONYMS
(Continued)

SCP	Sector Control Plan
SIA	Status Information Area
SME	Subject-Matter Expert
STE	Sector Traffic Events
SWAP	Severe Weather Avoidance Procedure
VFR	Visual Flight Rules
VOR	Visual Omni Range
VORTAC	Visual Omni Range Tactical Air Navigation
WAFDOF	Wrong Altitude For Direction of Flight
WF	Weather Factors

X. GLOSSARY OF STRATEGIES

X. GLOSSARY OF STRATEGIES

Are there conflictions or potential conflictions?	One of the planning category strategies where the controller determines if there are current or potential conflictions.
Are there times of heavy sector traffic and workload?:	One of the workload management category strategies where the controller looks ahead to identify times of heavy traffic.
Descend an aircraft to get the quickest separation:	One of the workload management category strategies where the controller decides which aircraft/action pair will achieve the quickest separation.
Determine action requiring minimum coordination:	One of the workload management category strategies where the controller identifies the control action that requires the least amount of coordination with other sectors.
Determine aircraft requirements:	One of the planning category strategies where the controller identifies the requirements of an aircraft or group of aircraft.
Determine amount of time available to affect separation once aircraft is in sector:	One of the planning category strategies where the controller determines if there is sufficient time to effect the required separation once an aircraft or set of aircraft have entered the sector.
Determine form of separation (e.g., vertical, lateral, or longitudinal separation):	One of the planning category strategies where the controller identifies the most efficient form of separation for a set of aircraft.
Determine how to expedite aircraft through your sector:	One of the workload management category strategies where the controller identifies a set of actions that will move an aircraft through the sector quickly.
Determine how weather and winds will affect the sector:	One of the planning category strategies where the controller determines how weather will affect the primary sector plan.
Determine sequence:	One of the planning category strategies where the controller identifies the sequence for landing aircraft.

X. GLOSSARY OF STRATEGIES

(Continued)

Determine the nature of the overtake:	One of the planning category strategies where the controller identifies the control requirements arising from a potential overtake.
Determine what to do to eliminate a factor:	One of the workload management category strategies where the controller decides on a set of actions that will remove an aircraft or set of aircraft from the problem.
Determine when to implement backup plan:	One of the planning category strategies where the controller decides when to terminate a plan and adopt the backup plan.
Determine when to start an action:	One of the planning category strategies where the controller identifies the point in time when to start one or a series of control actions.
Determine which action results in the lower workload:	One of the workload management category strategies where the controller identifies the most efficient set of actions from a workload perspective.
Determine which aircraft to make first (in line):	One of the planning category strategies where the controller identifies which aircraft, from a group, will be made first to arrive at the fix or gate.
Develop backup plan:	One of the planning category strategies where the controller makes an alternative plan to his or her overall sector plan.
Develop early primary sector plan:	One of the planning category strategies where the controller develops a primary sector plan based on strips and knowledge of the sector.
Does the aircraft require special attention?:	One of the planning category strategies where the controller identifies the aircraft in his or her sector that will require special services or monitoring.
Evaluate adjacent sectors:	One of the monitoring category strategies where the controller monitors adjoining sectors to anticipate future traffic or conflicts.

X. GLOSSARY OF STRATEGIES

(Continued)

Identify aircraft that are not a factor:	One of the workload management category strategies where the controller identifies aircraft that do not affect the problem.
Is it efficient to assume early control (reaching out)?:	One of the workload management category strategies used to initiate a set of actions before the aircraft has entered the sector.
Let speed take effect:	One of the planning category strategies where the controller waits to allow the aircraft speed to provide separation rather than vectoring the aircraft.
Monitor action to completion:	One of the monitoring category strategies where the controller monitors the aircraft after the control action has been taken.
Monitor separation:	One of the monitoring category strategies where the controller observes the separation between aircraft.
Monitor sequencing:	One of the monitoring category strategies where the controller observes the aircraft sequence to make sequencing decisions.
Monitor to compare strips with PVD data:	One of the monitoring category strategies where the controller checks the data on the strips against the radar data on the PVD.
Monitor to review and update control action plan:	One of the monitoring category strategies where the controller reviews aircraft data in order to update the control action plan.
Monitor to start action:	One of the monitoring category strategies where the controller observes aircraft to help determine when to start a control action.
Monitor to update primary sector plan or implement backup plan:	One of the monitoring category strategies where the controller reviews radar and/or strip data to update the primary sector plan.
Monitor to vector aircraft:	One of the monitoring category strategies where the controller observes aircraft route and separation to determine when to vector.

X. GLOSSARY OF STRATEGIES
(Continued)

Monitor to verify aircraft has reached altitude:	One of the monitoring category strategies where the controller observes an aircraft to determine when it is at altitude.
Monitor workload:	One of the workload management category strategies where the controller monitors his or her performance and behavior, and the level of traffic, to determine the amount of workload.
Prioritize actions:	One of the planning category strategies where the controller determines the priority for a set of control actions that need to be executed.
Refine and update primary sector plan or action plan:	One of the planning category strategies where the controller updates the primary sector plan or the short-term action plan.
Select action that will require least monitoring:	One of the workload management category strategies where the controller identifies the action or set of actions that will result in the least amount of monitoring.
Wait and see:	One of the planning category strategies where the controller decides to wait before developing or revising a primary sector plan or action plan.
What are the aircraft variables including altitude, speed, route, and traffic?:	One of the planning category strategies where the controller identifies the key attributes of an aircraft.
What are the aircraft's performance class or characteristics?:	One of the planning category strategies where the controller classifies an aircraft's level of performance for the purpose of determining sequencing, routing, or separation actions.
Which action can be completed the quickest?:	One of the planning category strategies where the controller determines which of several competing actions can be completed in the shortest amount of time.

COGNITIVE TASK ANALYSIS OF EN ROUTE AIR TRAFFIC CONTROL: MODEL EXTENSION AND VALIDATION

Volume II. Appendixes

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APPENDIX A. MENTAL MODEL AND TASK DECOMPOSITION VALIDATION STUDY TIMELINE

VALIDATION STUDY TIMELINE

Time	Current Task Event	Triggers To Task	Relevant Information From Mental Model	Pertinent Mental Model Panel: *Levels*	Controller Operations
00:01	Maintain Situation Awareness	Accept control of sector Subgoal: Determine traffic type Subgoal: Determine weather factors	N90CS route over MIO UAL42 over MIO to Dallas Weather system over MIO	AD: *Traffic Type/Route, Speed* STE: *Ongoing Events* WF: *Thunderstorms*	
00:37	Issue Weather Advisory	Aircraft within range of weather system No critical task in progress	See Time 00:01	See Time 00:01	Issue weather advisory to N90CS
01:00	Maintain Situation Awareness	Subgoal: Observe aircraft data on FPS Subgoal: Evaluate new sector feature	New approach to Dallas on flight strip for DAL612	SA: *Published Arrivals, Departures, Approaches*	Project route for DAL612 on PVD to see path of new approach
01:43	Manage Departures	Departure clearance request	Departure clearance request from MIO flight service regarding N342DK No flights in potential confliction with this departure	AD: *Altitude, Location, Traffic Type/Route* STE: *Aircraft Entering Sector* SCP	Clear departure of N342DK off MIO; request notification of reaching 3,000 feet in altitude Monitor situation

VALIDATION STUDY TIMELINE
(Continued)

Time	Current Task Event	Triggers To Task	Relevant Information From Mental Model	Pertinent Mental Model Panel: *Levels*	Controller Operations
02:49	Receive Handoff	Aircraft approaching sector Pilot on frequency prior to handoff	FDX33 approaching sector Low overall workload for sector No planes a factor reference FDX33 at present	STE: *Aircraft Entering Sector, Potential Conflictions* SCP: *Primary and Short-Term Plans*	Coordinate with adjacent sector to receive early handoff on FDX33 Leave FDX33 at present altitude
03:43	Manage Departure (See Time 01:43)	Departure clearance request	Departure clearance request from MIO flight service re N33FH N342DK climbing to 3,000 feet	AD: *Altitude, Location, Traffic Type/Route* STE: *Aircraft Entering Sector, Ongoing Events, Potential Conflictions* SCP	Hold N33FH for release in order to provide separation with N342DK Monitor situation
05:21	Manage Arrival	Aircraft landing at airport	Filed route for AAL61 not per procedure for Tulsa approach	AD: *Traffic Type/Route* SCP: *Long-Term and Short-Term Plan* Procedures: *Sector-Specific Procedures*	Assess sequence with AAL85 into Tulsa; no conflicts with other aircraft Issue route to AAL61 that will comply with LOA at Tulsa Monitor situation

VALIDATION STUDY TIMELINE
(Continued)

Time	Current Task Event	Triggers To Task	Relevant Information From Mental Model	Pertinent Mental Model Panel: *Levels*	Controller Operations
06:19	Manage Departure (See Time 03:43)	Earlier departure clearance request	N33FH awaiting departure off MIO Call from N342DK, leaving 3,000 feet triggers awareness that N342DK is adequate distance from airport to clear N33FH No planes a factor reference FDX33 at present	AD: *Altitude* STE: *Aircraft Entering Sector, Ongoing Events* SCP	Clear N33FH for departure Monitor situation
06:39	Manage Arrival	Aircraft landing at airport	Filed route for AAL85 not per procedure for Tulsa approach	AD: *Traffic Type/Route* SCP Procedures: *Sector-Specific Procedures*	Issue route to AAL85 in compliance with LOA at Tulsa Monitor situation

VALIDATION STUDY TIMELINE
(Continued)

Time	Current Task Event	Triggers To Task	Relevant Information From Mental Model	Pertinent Mental Model Panel: *Levels*	Controller Operations
07:27	Manage Departure (See Time 06:19)	N33FH call upon departure from MIO	N33FH, N90CS, N342DK separated by distance and altitude	AD: *Altitude, Location, Traffic Type/Route, Aircraft Speed, Aircraft Characteristics* STE: *Ongoing Events, Potential Conflictions, Events Nearing Completion* SCP	Issue maximum requested altitude to N33FH Monitor situation
07:44	Receive Handoff Manage Departure Flow	Flashing data block on NWA23 from Tulsa approach sector	NWA23 potentially altitude separated reference N342DK No other traffic noticed (results in later potential confliction)	AD: *Altitude, Traffic Type/Route* STE: *Aircraft Entering Sector, Potential Conflictions, Events Nearing Completion* SCP	Issue maximum requested altitude to NWA23

VALIDATION STUDY TIMELINE
(Continued)

Time	Current Task Event	Triggers To Task	Relevant Information From Mental Model	Pertinent Mental Model Panel: *Levels*	Controller Operations
08:00	Maintain Situation Awareness	Subgoal: Observe aircraft data on FPS	Mechanical problem with flight strips in strip bays Unable to keep up comfortably with sector traffic plus this "equipment" failure No assistant controller available	CF: *Traffic Volume/ Complexity, Sector Equipment Status, Personal Factors* ASF: *Staffing Factors*	Awareness that workload is uncomfortably high
08:50	Manage Departure	Departure clearance request	Clearance request for R43712 of MLC to PNC AAL85 descending in vicinity to arrive at Tulsa	AD: *Altitude, Location, Traffic Type/Route* STE: *Aircraft Entering Sector, Ongoing Events* SCP: *Short-Term Plan*	Issue clearance to R43712 for initial climb to 9,000 feet in order to keep this aircraft under AAL85 approaching Tulsa for landing
09:11	Manage Arrival (See Time 06:39)	Aircraft landing at airport	AAL85 nearing Tulsa airspace Aircraft needs to be maintained on arrival path	AD: *Altitude, Location* STE: *Ongoing Events* SCP	Give AAL85 clearance to descend to 21,000 feet Monitor situation

VALIDATION STUDY TIMELINE
(Continued)

Time	Current Task Event	Triggers To Task	Relevant Information From Mental Model	Pertinent Mental Model Panel: *Levels*	Controller Operations
09:27	Manage Departure	Aircraft not at final altitude AAL61 on same flight path in opposite direction	Call from SWA44 off Tulsa approach	AD: *Altitude, Location, Traffic Type/Route, Speed* STE: *Aircraft Entering Sector, Ongoing Events, Potential Conflictions* SCP	Climb SWA44 to 19,000 feet as initial altitude Monitor situation regarding potential conflict with AAL61, PAA23
09:40	Manage Departure (See Time 08:50)	Earlier departure clearance request	R43712 departing MLC airport, destination Hot Springs No conflicting traffic in or approaching flight path of R43712	AD: *Altitude, Traffic Type/Route* STE: *Aircraft Entering Sector, Ongoing Events* SCP: *Primary and Short-Term Plans*	Assess status of traffic reference R43712 Climb R43712 to 10,000 feet (thus separated from all other current traffic)
09:53	Manage Arrival (See Time 05:21)	Aircraft converging on airport	AAL61 approaching Tulsa	AD: *Altitude* STE: *Ongoing Events*	Descend AAL61 to 21,000 feet Monitor situation
10:09	Resolve Aircraft Conflict	Two aircraft converging on same location, altitude	NWA23 and DAL612 converging on same location, same altitude	AD: *Altitude, Location* STE: *Ongoing Events, Potential Conflictions* SCP	Evaluate potential confliction between DAL612 and NWA23 Descend NWA23 to 19,000 feet to resolve conflict with altitude separation

VALIDATION STUDY TIMELINE
(Continued)

Time	Current Task Event	Triggers To Task	Relevant Information From Mental Model	Pertinent Mental Model Panel: *Levels*	Controller Operations
10:34	Maintain Situation Awareness	Subgoal: Evaluate aircraft data and determine events in sector	Initial call from SWA27 Workload high Mechanical problem with flight strips	AD: *Traffic Type/Route* STE: *Ongoing Events, Potential Conflictions* SCP: *Short-Term Plan* ASF: *Staffing Factors* CF: *Traffic Volume/ Complexity, Sector Equipment Status, Affective Factors*	Too jammed up to sort through flight strip bay No help available Project route readout for SWA27 on PVD
10:36	Manage Departure	Aircraft departing airport	SWA27 departing Tulsa No potentially conflicting traffic	AD: *Altitude, Location, Traffic Type/Route* STE: *Aircraft Entering Sector, Potential Conflictions* SCP	Climb SWA27 to highest requested altitude
11:46	Manage Arrival (See Time 09:11)	Aircraft converging on airport	AAL85 approaching Tulsa Other aircraft in general proximity	AD: *Altitude, Location* STE: *Ongoing Events, Potential Conflictions* SCP: *Short-Term Plan*	Descend AAL85 to 12,000 feet Monitor situation

VALIDATION STUDY TIMELINE
(Continued)

Time	Current Task Event	Triggers To Task	Relevant Information From Mental Model	Pertinent Mental Model Panel: *Levels*	Controller Operations
12:17	Resolve Aircraft Conflict	Two airplanes converging on same location at same altitude	PAA23 and FDX33 on intersecting flight paths	AD: *Altitude, Location, Speed* STE: *Potential Confliction* SCP	Assess potential confliction between PAA23 and FDX33 Descend PAA23 to 21,000 feet
12:40	Manage Departure Flow	Departure clearance request	Departure clearance request from MLC regarding N500TB Many traffic events in progress Critical tasks in progress Feeling of reacting to traffic	STE: *Aircraft Entering Sector* CF: *Traffic Volume/ Complexity, Personal Factors*	Place departure of N500TB on hold to manage high workload
12:50	Develop and Revise Sector Plan	New event in sector	JAL24 making initial radio contact; overflight	AD: *Altitude, Traffic Type Route* STE: *Aircraft Entering Sector, Potential Conflictions, Ongoing Events* SCP	Assess potential conflict with relevant traffic Keep JAL24 at present altitude out of way of other traffic

VALIDATION STUDY TIMELINE
(Continued)

Time	Current Task Event	Triggers To Task	Relevant Information From Mental Model	Pertinent Mental Model Panel: *Levels*	Controller Operations
13:20	Initiate Handoff (See Time 10:36)	Aircraft preparing to exit airspace No more control actions necessary	SWA27 at final altitude, approaching sector boundary No traffic in vicinity	AD: *Altitude, Location, Traffic Type/Route* STE: *Events Nearing Completion* SCP: *Short-Term Plans*	Initiate handoff to receiving controller Monitor for acceptance of handoff
13:33	Resolve Aircraft Conflict (See Time 12:17) Develop and Revise Sector Control Plan	Two or more aircraft converging on same location at same altitude Discrepancy with plan	SWA44, PAA23, and AAL61 converging AAL61 needs 11,000 feet for arrival into Tulsa PAA23 at 21,000 feet for separation from FDX33 SWA44 climbing slowly	AD: *Altitude, Location, Traffic Type/Route, Aircraft Characteristics, Aircraft Speed* STE: *Ongoing Events, Potential Conflictions* SCP	Climb SWA44 to 10,000 feet and hold there until other traffic is laterally separated Monitor situation
14:00	Reroute Aircraft	Clearance request from pilot	Request from NWA23 to deviate west of weather system over MIO No other aircraft a factor reference this location	AD: *Altitude, Location* STE: *Ongoing Events, Potential Conflictions* WF: *Thunderstorms*	Issue clearance to deviate west of weather Monitor flight path of NWA23

VALIDATION STUDY TIMELINE
(Continued)

Time	Current Task Event	Triggers To Task	Relevant Information From Mental Model	Pertinent Mental Model Panel: *Levels*	Controller Operations
14:08	Manage Arrival (See Time 09:53)	Aircraft converging on airport	AAL61 nearing Tulsa approach AAL85 also approaching Tulsa	AD: *Altitude, Location, Traffic Type/Route* STE: *Ongoing Events* SCP	Slow AAL61 to 250 to put well behind AAL85 Monitor situation
14:33	Initiate Handoff (See Time 10:36)	Aircraft preparing to exit airspace	Handoff on SWA27 accepted by receiving controller	AD: *Location* STE: *Events Nearing Completion*	Switch radio frequency for SWA27 to receiving sector
15:32	Manage Arrival (See Time 11:46)	Aircraft converging on airport	AAL85 nearing Tulsa approach	AD: *Altitude, Location, Speed* STE: *Ongoing Events* SCP	Descend AAL85 to 11,000 feet, reduce speed to 250 Monitor situation
15:40	Initiate Handoff (See Time 07:27)	Aircraft preparing to exit airspace No remaining control actions	N33FH nearing sector boundary No other traffic a factor reference this aircraft	AD: *Traffic Type/Route* STE: *Events Nearing Completion*	Coordinate with receiving sector Switch radio frequency for N33FH

VALIDATION STUDY TIMELINE
(Continued)

Time	Current Task Event	Triggers To Task	Relevant Information From Mental Model	Pertinent Mental Model Panel: *Levels*	Controller Operations
16:20	Reroute Aircraft (See Time 14:00)	Request from pilot	Call from NWA23 requesting to resume own course	AD: *Traffic Type/Route* STE: *Events Nearing Completion*	Approves request to resume navigation per filed flight plan
16:29	Initiate Handoff (See Time 16:20)	Aircraft preparing to exit airspace No remaining control actions	All control actions complete on NWA23	AD: *Traffic Type/Route* STE: *Events Nearing Completion*	Initiate handoff to receiving sector Monitor for acceptance of handoff
17:14	Initiate Handoff (See Time 15:32)	Aircraft preparing to exit airspace	Auto handoff accepted by Tulsa approach for AAL85	STE: *Events Nearing Completion*	Radio switch AAL85 to Tulsa approach
17:20	Develop and Revise Sector Control Plan	New event in sector	Call from N66SR for vectors to MLC approach No other traffic anticipated as a factor for N66SR landing at MLC	AD: *Location, Traffic Type/Route* STE: *Ongoing Events* SCP	Delay giving vectors to N66SR until in closer proximity to airport Attend to higher priority tasks
17:39	Manage Departure	Aircraft not at final altitude	Call from NWA56 handed off from Tulsa approach	AD: *Altitude, Location, Traffic Type/Route* STE: *Aircraft Entering Sector* SCP: *Short-Term Plans*	Acknowledge call from NWA56 Observe route Delay control actions while attending to other priorities

APPENDIX B: STRATEGY LISTINGS FOR EACH PROBLEM AND PARTICIPANT GROUP

APPENDIX B

PERCENTAGE OF THE PRIMARY STRATEGIES USED IN STRUCTURED PROBLEM 1

	EXPERIENCE LEVEL*		
STRATEGY	**EXP**	**INT**	**NOV**
Monitor separation	21%	25%	22%
Refine and update primary sector plan or action plan	15%	17%	7%
Monitor action to completion	6%	3%	2%
Monitor to vector aircraft	6%	5%	7%
Determine when to start an action	6%	13%	10%
What is the aircraft's performance class or characteristics?	6%	1%	1%
Monitor sequencing	5%	4%	8%
Procedural or non-strategy related	5%	2%	10%
Determine time available to affect separation once aircraft is in sector	4%	2%	1%
Determine which aircraft to make first (in line)	3%	3%	2%
Identify aircraft that are not a factor	3%	0%	0%
Determine aircraft requirements	2%	1%	0%
Determine how to expedite aircraft through your sector	2%	1%	0%
Develop early primary sector plan	2%	1%	1%
Determine form of separation (e.g., vertical, lateral, or longitudinal separation)	2%	5%	3%
Let speed take effect	2%	3%	1%
Monitor to update primary sector plan or implement backup plan	2%	1%	5%
Prioritize actions	2%	1%	2%
Are there conflictions or potential conflictions?	1%	3%	3%
Determine sequence	1%	3%	6%
What are aircraft variables including altitude, speed, route, and traffic?	1%	0%	5%
Wait and see	0%	1%	4%
Which action can be completed the quickest?	0%	3%	0%
OTHER	5%	2%	2%
TOTALS**	102%	100%	102%

***KEY**

Exp = Expert
Int = Intermediate
Nov = Novice

** Totals may not add to exactly 100% due to rounding.

PERCENTAGE OF THE PRIMARY STRATEGIES USED IN STRUCTURED PROBLEM 2

	EXPERIENCE LEVEL*		
STRATEGY	**EXP**	**INT**	**NOV**
Procedural or non-strategy related	20%	17%	23%
Monitor separation	15%	17%	10%
Are there conflictions or potential conflictions?	8%	10%	5%
Identify aircraft that are not a factor	7%	4%	1%
What are aircraft variables including altitude, speed, route, and traffic?	7%	7%	7%
Determine sequence	5%	4%	3%
Determine aircraft requirements	4%	11%	3%
Determine form of separation (e.g., vertical, lateral, or longitudinal separation)	4%	5%	7%
Determine how to expedite aircraft through your sector	4%	0%	0%
Prioritize actions	4%	1%	3%
Determine when to start an action	3%	4%	0%
Monitor to vector aircraft	3%	1%	0%
Monitor to verify aircraft has reached altitude	2%	4%	9%
Wait and see	2%	3%	11%
Refine and update primary sector plan or action plan	2%	1%	3%
OTHER	2%	0%	3%
	0%	4%	6%
	10%	7%	5%
TOTALS**	102%	100%	100%

*KEY

Exp = Expert

Int = Intermediate

Nov = Novice

** Totals may not add to exactly 100% due to rounding.

PERCENTAGE OF THE PRIMARY STRATEGIES USED ACROSS BOTH STRUCTURED PROBLEMS

	EXPERIENCE LEVEL*		
STRATEGY	**EXP**	**INT**	**NOV**
Monitor separation	23%	27%	22%
Refine and update primary sector plan or action plan	10%	13%	8%
Identify aircraft that are not a factor	7%	2%	0%
Monitor sequencing	5%	3%	7%
Monitor to vector aircraft	5%	5%	12%
Determine when to start an action	5%	10%	13%
What are aircraft variables including altitude, speed, route, and traffic?	5%	5%	8%
Determine aircraft requirements	4%	7%	2%
Monitor action to completion	4%	2%	2%
Determine how to expedite aircraft through your sector	4%	0%	0%
Determine sequence	4%	5%	6%
What is the aircraft's performance class or characteristics?	4%	0%	0%
Determine form of separation (e.g., vertical, lateral, or longitudinal separation)	3%	6%	6%
Determine time available to affect separation once aircraft is in sector	3%	1%	1%
Prioritize actions	3%	1%	2%
Determine which aircraft to make first (in line)	2%	2%	2%
Determine how weather and winds will affect the sector	2%	3%	0%
Develop early primary sector plan	2%	0%	0%
Let speed take effect	1%	2%	0%
Monitor to update primary sector plan or implement backup plan	1%	1%	3%
Monitor to verify aircraft has reached altitude	1%	0%	2%
Wait and see	1%	1%	5%
Which action can be completed the quickest?	0%	2%	0%
OTHER			
TOTALS**	99%	98%	101%

***KEY**

Exp = Expert
Int = Intermediate
Nov = Novice

** Totals may not add to exactly 100% due to rounding.

COMBINED EXPERT STRATEGY LISTING—STRUCTURED PROBLEM 1

EXPERT STRATEGIES	FREQUENCY OF USE
Primary Sector Planning	
Develop early primary sector plan	3
Develop backup plan	1
Control Action Planning	
Refine and update primary sector plan or action plan	19
Determine when to start an action	7
What is the aircraft's performance class or characteristics?	7
Determine amount of time available to affect separation once aircraft is in sector	5
Determine which aircraft to make first (in line)	4
Determine aircraft requirements	3
Prioritize actions	2
Let speed take effect	2
Determine form of separation (e.g., vertical, lateral, or longitudinal separation)	2
What are the aircraft variables including altitude, speed, route, and traffic?	1
Evaluate flow control	1
Determine what to do to eliminate a factor	1
Determine sequence	1
Determine how weather and winds will affect the sector	1
Are there conflictions or potential conflictions?	1
Monitoring	
Monitor separation	26
Monitor to vector aircraft	8
Monitor action to completion	8
Monitor sequencing	6
Monitor to update primary sector plan or implement backup plan	2
Monitor to review and update control action plan	1
Workload Management	
Identify aircraft that are not a factor	4
Determine how to expedite aircraft through your sector	3
Is it efficient to assume early control (reaching out)?	1

COMBINED INTERMEDIATE STRATEGY LISTING—STRUCTURED PROBLEM 1

EXPERT STRATEGIES	FREQUENCY OF USE
Primary Sector Planning	
Develop backup plan	2
Develop early primary sector plan	1
Control Action Planning	
Refine and update primary sector plan or action plan	24
Determine when to start an action	18
Determine form of separation (e.g., vertical, lateral, or longitudinal separation)	7
Letting speed take effect	5
Determine which aircraft to make first (in line)	5
Determine sequence	5
Monitor action to completion	4
Are there conflictions or potential conflictions?	4
Determine amount of time available to affect separation once aircraft is in sector	3
Wait and see	2
Prioritize actions	2
What is the aircraft's performance class or characteristics?	1
Determine aircraft requirements	1
Monitoring	
Monitor separation	36
Monitor to vector aircraft	7
Monitor sequencing	6
Monitor to update primary sector plan or implement backup plan	2
Workload Management	
Which action can be completed the quickest?	4
Determine action requiring minimum coordination	1
Determine how to expedite aircraft through your sector	1

COMBINED NOVICE STRATEGYLISTING—STRUCTURED PROBLEM 1

EXPERT STRATEGIES	FREQUENCY OF USE
Primary Sector Planning	
Develop early primary sector plan	2
Control Action Planning	
Determine when to start an action	20
Refine and update primary sector plan or action plan	13
Determine sequence	11
What are the aircraft's variables including altitude, speed, route, and traffic?	10
Wait and see	8
Determine form of separation (e.g., vertical, lateral, or longitudinal separation)	5
Are there conflictions or potential conflictions?	5
Prioritize actions	4
Determine which aircraft to make first (in line)	4
Determine amount of time available to affect separation once aircraft is in sector	2
What is the aircraft's performance class or characteristics?	1
Let speed take effect	1
Identify aircraft that are not a factor	1
Determine when to implement backup plan	1
Monitoring	
Monitor separation	43
Monitor sequencing	15
Monitor to vector aircraft	14
Monitor to update primary sector plan or implement backup plan	9
Monitor action to completion	4
Workload Management	
Determine what to do to eliminate a factor	1

COMBINED EXPERT STRATEGYLISTING—STRUCTURED PROBLEM 2

EXPERT STRATEGIES	FREQUENCY OF USE
Control Action Planning	
Are there conflictions or potential conflictions?	9
What are the aircraft variables including altitude, speed, route, and traffic?	8
Determine sequence	6
Determine form of separation (e.g., vertical, lateral, or longitudinal separation)	5
Prioritize actions	4
Determine how weather and winds will affect the sector	3
Wait and see	3
Let speed take effect	2
Determine when to start an action	2
What is the aircraft's performance class or characteristics?	2
Does the aircraft require special attention?	1
Determine which aircraft to make first (in line)	1
Monitoring	
Monitor separation	17
Monitor sequencing	4
Monitor to verify aircraft has reached altitude	2
Monitor to vector aircraft	2
Monitor action to completion	2
Monitor to update primary sector plan or implement backup plan	1
Monitor to start action	1
Workload Management	
Identify aircraft that are not a factor	8
Determine how to expedite aircraft through your sector	4
Which action can be completed the quickest?	1
Determine what to do to eliminate a factor	1

COMBINED INTERMEDIATE STRATEGY LISTING—STRUCTURED PROBLEM 2

EXPERT STRATEGIES	FREQUENCY OF USE
Primary Sector Planning	
Develop backup plan	1
Control Action Planning	
Determine aircraft requirements	15
Are there conflictions or potential conflictions?	14
What are the aircraft variables including altitude, speed, route, and traffic?	10
Determine form of separation (e.g., vertical, lateral, or longitudinal separation)	7
Determine how weather and winds will affect the sector	6
Refine and update primary sector plan or action plan	5
Determine when to start an action	5
Determine sequence	5
Determine which aircraft to make first (in line)	2
What is the aircraft's performance class or characteristics?	1
Prioritize actions	1
Determine amount of time available to affect separation once aircraft is in sector	1
Monitoring	
Monitor separation	23
Monitor vector aircraft	4
Monitor to verify aircraft has reached altitude	1
Monitor to update primary sector plan or implement backup plan	1
Monitor sequencing	1
Workload Management	
Identify aircraft that are not a factor	5
Is it efficient to assume early control (reaching out)?	1
Determine what to do to eliminate a factor	1
Determine action requiring minimum coordination	1

COMBINED NOVICE STRATEGY LISTING—STRUCTURED PROBLEM 2

EXPERT STRATEGIES	FREQUENCY OF USE
Primary Sector Planning	
Develop backup plan	1
Control Action Planning	
Determine when to start an action	13
What are the aircraft variables including altitude, speed, route, and traffic?	11
Determine form of separation (e.g., vertical, lateral, or longitudinal separation)	11
Refine and update primary sector plan or action plan	9
Are there conflictions or potential conflictions?	8
Wait and see	5
Determine sequence	5
Determine aircraft requirements	4
Let speed take effect	2
What is the aircraft's performance class or characteristics?	1
Determine the nature of the overtake	1
Monitoring	
Monitor to vector aircraft	17
Monitor separation	15
Monitor to verify aircraft has reached altitude	4
Monitor sequencing	4
Monitor to start action	1
Workload Management	
Determine what to do to eliminate a factor	2
Identify aircraft that are not a factor	1

APPENDIX C: STRATEGY VALIDATION INTERVIEWS

Summary from B03

Letting speed take effect: What they learn at the Academy is that if someone requests 19,000 off the ground, you have to give him 19,000 on the immediate departure and they downgrade him for not doing that. That is in the classroom, in the field we tell them that they can only criticize you for over-controlling, they can fire you for undercontrolling. I have no qualms about going over to a sector and asking, "What are you using here?", and if he says, I am working with speed, well what if speed is not going to work? You always ask that "What if?". You have to have more than one plan, and I as a supervisor will not accept from a controller that this is the only plan that he will use. So if that is the case, I would say that using speed as the sole thing is not used that much.

Speed up to expedite: We use that quite a bit. You will speed up to expedite and we also do it for en route spacing. We will start adjusting far back for this.

Early control: If you call for an early handoff, tell the other sector why because you want to coordinate something with that sector. So do not make wasted calls, do it all at one time. In your pre-planning, if you are going to reach out and get control of an airplane, you are going to reduce that coordination. If you are going to call someone to APPREQ something with them, don't tell him just part of the story, tell him all of the story. By spelling out the story, it can get resolved before it gets into your airspace.

Eliminating a factor: You have to find the key factor. Where is the key to this problem? There could be two or three. You eliminate those . . . . Once you have done your pre-planning, then you do your projecting. If he is going to be a factor, then resolve that factor. If you have a situation with an overflight crossing the arrival routing, you can do one of two things: re-route the aircraft away from the arrival routing that would least impede the pilot, or give him a lower or higher altitude, and take that aircraft out of that situation. Experience will tell you that if you let them fly and see how they will fit, they have never fit yet. So you pre-plan and then project. What is this going to do to me before I get them, and then what is it going to do to me when I get them and after I get them? So there are three stages there. You look at the strips (time sequences) and then at the altitudes (see, do I have conflictions there?). Then check the routings, you may have two at the same altitudes, but their routings are not a factor. You look at your arrivals, then look at the height of the arrivals and go back and start eliminating factors.

Your pre-planning starts when that strip hits the board. When you take that strip, you look down the bay and ask what that does to me. This guy is at 10,000, do I have any other 10's? What is his routing? Then you determine if he is going to be a problem. In eliminating a factor, look at departures off of non-approach control airports. In lab situations you are taught to give departures the highest optimum altitude or their altitude. On the floor in the control room, you don't do it that way. You give him an altitude that works for you and him. Give him 4 to 5,000 feet to climb, without clearing him all the way. So you don't build yourself a trap.

Determining most time-critical problem: The reason this is rated at a lower level of experience is that in any type of a control environment, your actions are more than likely affecting the next area of the next facility. So you have got to know these things to make it work. With regard to this coming into play, I had a situation where I had a King Air southbound between Wichita and Ponca City, and a DC-9 over Ponca City landing McConnell that wanted lower altitude. The King Air was at 16,000 so I gave the DC-9 17,000. When they were about 8 miles apart, I issued traffic, and when they were 5 miles apart, I issued traffic again because I said he was just leveling off at 17,000. The next update on the scope is that he is out of 16,600. I hollered at him to check his altitude immediately, and gave the King Air an immediate left turn, 90-degree turn. One of the pilots came back and said that he just passed under me. I was hoping it was the DC-9 saying that and not the King Air. It was a situation that you are just sitting there issuing traffic. The next thing you know there is an update at 16,800 and then one at 16,400, and he just kept going on down. After the investigation, the pilot had drawn a blank because we always used to send them into McConnell at 10,000.

In determining the next critical factor, first of all you look at what is there already, aircraft that are level, to determine if they are going to be a potential. Do we have a confliction or crossing point? That is a quick check. Then immediately you look at those that are climbing or descending to make sure that they are not a potential. Then you look at those that are departing or arriving from a non-approach-type airport. Try to keep it them in that order. Once you resolve your potential conflictions, the next thing you want to do is make sure that your coordinating is prioritized: complying with letters of agreement, adjacent airspace, who needs to be handed off, who needs to be coordinated with, etc. Step three is, what is going to be easier for me? What is going to make my job easier? Now coupled with step three is, how can I give the best service? The biggest problem with the new students is the lack of equipment knowledge. Not knowing how to put in the proper sequence is a distraction for what they are doing. If the developmentals don't know their area, don't know their equipment, and don't know how to use it, those three things distract from what they really need to know and need to be doing.

If you have to stop and think when you clear an airplane, rather than knowing what that airplane is going to do . . . . We get a lot of students who still do not understand non-radar. They cannot control what they cannot see because they cannot visualize. I will take a new student and have them close their eyes and ask them which way is north, and which way is south, and if you can fix the directions in your mind, you do not have to have a radar scope. For example, if you have a plane taking off to the northwest, and then making a left turn, you have to know what directions are involved. With the 3-D, if you have planes at 6 and 7,000, and you want to climb the departure to 8,000, then you have to start from ground zero and figure in your mind the critical angle of that departure. If you do not know the area, if you cannot punch this stuff into the computer . . . . The developmentals have no idea what a 300 system is. So you say call sector X, and they have no idea. All they need is a day on the 300 system. I would extend the course here by a week and have nothing but basic computer entries, so that there would be fewer distractions from your primary job, separating airplanes.

Determining which action requires minimum coordination: You need to learn this very early on or you can build yourself into a box so quickly if you don't. In our center we have a side-by-side scope situation . . . . If you are dealing with high altitude, reaching out is about 90% of high altitude. Low altitude, you are dealing with lower and slower airplanes except for departures and arrivals, and those are on a fixed route so you don't have to reach out as much. Except when there are going to be dead ties at the arrival fix, you will reach out then. A good controller will call up and say, do this or that for me. You don't want to call up a sector and say I want it this way and no other way, because it may not fit into their situation. You want them to look at these two, and put one ahead or one behind, or something like that. When you wait, and the problem is in your immediate sector, you have waited too long. If you have a problem, and you don't have two possible solutions before they get to your sector, you have waited too long. You have to do pre-planning. If you have to wait until they flash, you did not see the situation.

Early handoff: Used frequently. If you are done with that airplane, hand him off to the next sector.

Determining the most efficient order: Always have more than one plan. Until you are sure that plan A is going to work, have an ace in the hole. So, have them separated by altitude first. In pre-planning, select that plan that will work the best based on your first calculation. That is why you need more than one plan. As the plan gets closer, then you have to be able to convert to that other plan. Until you have positive separation, always have separation in mind.

Determining route with minimum traffic impact: This is done often, and is insisted on by the instructor.

Determine aircraft capabilities (performance): This is done very often and should be learned at the earliest stages. Two of the most important factors are aircraft speed and climb rate, and the fact that within 30 miles of a metropolitan area they can only go so fast until they are out of 10,000 feet. Lots of trainees don't understand this. You have two planes, and I am going to let them fly since I have 20 miles apart, and they fail to realize that the plane is going to slow up before it gets to 10,000 feet. If you don't have something done with the back one, he is going to catch up. You don't wait until they are on top of each other to make that decision. Usually you ask the lead plane to advise when he is reduced below a certain amount. Then you tell the next one, and have him advise. I have to know the normal climb and descent rate for the various aircraft. The key performance things they should know are:

Certain classes of aircraft climb so fast
All aircraft have to stay at 250 knots or less until they are out of 10,000 feet
Jet ground speed in level flight is 450 knots
Don't use indicated airspeed above 29,000 feet (use mock speeds)

Determine if the aircraft can be cleared direct: There are a number of sector limitations which make its frequency somewhat less. You have to know the full restrictions in order to use this.

How to decompose the problems: This is done most frequently. If you cannot see the immediate problems, you cannot be working the sector. Your solution is another issue. In decomposing a problem, you eliminate your potential conflictions first, then your coordination, then things that you need to do. The last thing is service to the pilot. Some common errors in this area is that trainees focus on just one area, letting go of other parts. When we grade trainees, we look for separation, control actions, planning. Some of the lowest priority things are communication and working speed. As they progress through, then working speed becomes a factor. In teaching how to separate, you have to teach trainees how to look beyond the immediate situation. You are going to separate A from B, but look beyond this situation to see what it is going to do to C or D. Before you finalize your plan, look beyond, by projecting out. So before you execute, you need to project.

Regarding projecting, you have to know what all aircraft are doing in your area because certain things are repetitious. You learn to determine sector-normal events, then you look to determine what the abnormals are (such as military). You then fix in your mind what all the planes are going to do, and the keys are your abnormals. You can then eliminate the abnormals or at least make sure that you make a corrective action. You first look at what you have got, then you look at what is coming. Everyone has a different technique, and that is why you match trainees with as many controllers as possible, so they can pick up some of these techniques. You then modify those techniques that will work for you. Those without technique are usually the ones who deal in "flash control," the ones who do not have any pre-planning. A more experienced controller can tell where a trainee may have picked up a technique. One example of technique is turning both planes a little to ensure separation rather than turning just one with a large turn. This is a technique where you do not want aircraft to get too far off course. Some controllers vector very little, and just change altitude. A poor technique is reflected in someone who does not do anything until the conflict goes off. Another poor technique is found with controllers who are afraid to say "unable." Another technique is making the faster airplane first when you have a tie. Another technique is vectoring for final of fanning aircraft.

The best learning period for new controllers is the first week when you are all alone. Old controllers are not fast, but they should know how to make things easier for themselves. You lose that sharpness after age 40, so you use pre-planning more carefully. The unique thing about controlling is that you learn new things every day.

Making things easier for yourself: One of the key strategies I use is to separate the normal from the abnormal. The ultimate thing is pre-planning. Have a control action plan, and have more than one. Once you separate your normal from the abnormal, you start your pre-planning.

Pre-planning: Some controllers, by the way they position their data blocks, indicate what they have planned for the specific aircraft. Also figure out another decision point, so that if your plan is not working, you will know when to activate plan B. When there is weather involved, it is entirely a different type of control. So you give yourself a bigger break in weather. You use a whole different technique.

Are there any other strategies: Not anything that I can think of.

Summary from B05

Shortcutting: Trainees tend to put themselves into situations where they tend to be too conservative and cause themselves problems. They may stop all aircraft at 27,000 because they think it is a safe altitude rather than getting up to where they should be. They may get so busy that they then do not have time to work with them.

Letting speed take effect: Since I am a high-altitude controller working primarily with jets where speed control is not very effective, I do not use it very much. When I use it, I use it in combination with the wind. It can be very effective if you combine a small turn toward the wind with a speed reduction; it will take effect very quickly. Conversely, if you don't take wind into account, such as reducing a turn with the wind, you will not get the reduction. I use speed mostly to stabilize what I have rather than control an overtake. Therefore, at high altitude, you do not use speed as much because it takes too long to take effect. There may also be a factor that pilots may not be in a hurry to comply. Trainees use it too much, and they rely on it when they should be using other forms of separation. They should not even consider using it in a fairly rapid overtake situation. Sometimes trainees do not understand the difference between indicated and mock speeds. As you descend, if you ask a pilot to maintain 250 knots indicated, you are forcing him to throttle back and his ground speed is going down. Above 29,000 almost everyone uses mock number. Below that, you will see controllers using indicated more. A lot of the new controllers will question the use of 29,000 as the cutoff, but from experience it seems valid.

Early control: I use it quite a bit. It depends on the amount of time available to affect separation at the point that I no longer have to reach out. In average traffic, if I have 4 or 5 minutes to affect separation, I will not reach out. If I have only 2 or 3 minutes, I will call the next sector. In heavy workload I become more conservative. I would take care of it no matter what.

Eliminating a factor: I do not use it much. As you become more experienced, your ego becomes such that you want to finesse the situation. Therefore, with confidence, you may not want to make the more radical move necessary to eliminate a factor. Therefore, I may take more steps to provide more service to the airline. Thus, I may make minor moves that marginally affect two aircraft rather than just hammer one. If I had to, I could take him out of my sector, but I may mess up the sector below.

The notion of finessing: Trying to do something in the most professional manner as it applies to the airlines rather than to you. You may increase your workload, but you are doing it for the benefit of the pilot. This can include becoming involved with more than one aircraft (turning 3 aircraft 15 degrees each rather than turning one 60 degrees). Increasing your workload by watching someone more carefully. You can cause a heavy workload by finessing too much.

Sequence to minimize own workload: Do not do it often. By scanning far out, you may call other sectors to reduce a possible conflict in your sector.

Determining most time-critical problem: The bottom line is basic separation. When you see that two aircraft at the same altitude are going to be at the same place at the same time, you take care of that first. Once you are past the immediate situations (where you are going to lose separation), next is sequencing of arrivals. I also consider how it will affect the next sector. I try not to increase his workload. Once I have separated my aircraft, I try to be as efficient as possible by selecting those things that cause the most effect with the least amount of work. Since my sector has a lot of arrivals to sequence, that is a big priority for us and a high priority.

Determining which action requires minimum coordination: The secret to this is trying to project two or three moves ahead and see how what you do will affect the overall picture. Sometimes you make a move without realizing that three minutes ahead the first move will cause you to do something else with the airplane. If you have a good overall picture of the situation, you can project forward and avoid some of these problems. Usually, in a heavy traffic situation, it is difficult to do.

Projecting: I do that often and it is based on experience gained in a specific airspace. If I know that at 9 in the morning, Atlanta is going to fire 40 departures out to the southeast, I am more inclined not to climb someone who is going to cross out with all those departures. You may know that other sectors will have other problems at certain times of the day. If you are in the middle, and the person above is down the tubes every day at 9:30, then you don't take everyone to 29 thinking that you will get rid of them. Do not put yourself in the situation where you are dependent on someone else's actions to bail you out. Always have an out: plans B, C, and D.

Determining the most efficient order: Don't use it often with carriers. You have to know aircraft characteristics. Sometimes I will see controllers request an aircraft to do something that they cannot do. You need to consider aircraft speed, performance, and altitude ability.

Determining route with minimum traffic impact: This is sector-specific based on the time of day. You do pull aircraft away from VOR's trying to keep everyone from getting to the same spot at the same time.

Determining if an aircraft can be cleared direct: I do not do it a whole lot. My consideration is what impact it will have on the sectors around me. You can clear direct, but you have to make sure that you are not hurting someone down the road.

Pre-planning (off the strips): We do not do it often. The problem is that you tend to operate in a radar environment and you think in a radar environment. For me, I can separate most guys that they send me. When I do use strips, it is probably in the light to moderate situation. In heavy workload, you prioritize and project.

Other strategies: I like to consider people working around me. I take into consideration time-frames and departure and arrival streams. So I monitor and control workload to make sure I am ready for those peak times. Equipment is a factor. If I know that a frequency has gone out three times in the last month, I will be more careful listening for readbacks. VOR's can be unreliable. Winds are a big factor, especially in making turns.

Summary from B06

Shortcutting: Frequency is about 6 or 7 and it is used also as a service. If the sector is slow, it is an easy thing, but in the situations where there is a heavy workload, it is much harder to do because it takes time to figure long-range fixes. Errors are made because the person does not see the long-range effect of the action . . . . If the instructor has not let the trainees know what the traps are . . . .

Letting speed take effect: This is used quite a bit, so it would get a 5. One of the hardest things to get across to new trainees is to have the patience to get it to work. ATP teaches that vectoring is preferable to speed control, but there are times where speed is important. At high altitude, there are high-speed and low-speed stall factors, pilot concurrence is required, the type of equipment is a factor. It can be a complicated thing to do. On speed control in the high-altitude stratum, if you have three DC-10's going the same route, we know that a DC-10's normal Mach number is .83 (290 knots) at 35,000. If they are in trail, you would know to just leave them. But if you added a 737 to the above situation, you would know that you could have an overtake. If you are trying to set up a single stream for major terminal area, then it is a single stream with hard speeds. There are also aircraft variables, like a 727 at 39,000. He does not have much to play with (±5 to 7 knots) because of the high-speed/low-speed stall. You may have to drop him so he can comply with the speed restriction. Another thing that you have to be aware of is turbulent weather. You will not get a pilot to push his speed in cases of turbulent weather. Common errors include too drastic a speed reduction, or expecting too much of a speed increase. Some of the trainees are not aware of a high-or low-speed stall. . .also, they may have trouble remembering that pilot concurrence comes into play.

Early control: This is used frequently in some sectors. You may have to turn the guy to get him to fit into the situation. It may be easier to reach out and turn him while you have the room instead of S turning him. On descent, some of that is covered by letter of agreement. If it is not covered, then it depends on the traffic situation. If you need to, then do it, otherwise, do not bother the plane. One of the errors is doing coordination that is unnecessary or just doing it wrong, where you don't comply with the letters of agreement, or you put aircraft into conflict.

Eliminating a factor: If you have weather in your sector, you may have your supervisor advise adjoining sectors to single stream or re-route before they join your sector. During normal traffic situations you might do that once an hour. It is used quite frequently. An error may be eliminating one factor only to cause another.

Sequence to minimize own workload: In sequencing, one of the first questions to ask is, "Do I have to talk to anyone?" I try to wait until the aircraft is in my sector to eliminate coordination. In the case of ties, I can use equipment type to determine the sequence. Depending on where the sequencing takes place, if it is a short run or relatively close, I may not have a choice but to reach out. If it is a long-range thing, with similar-type aircraft, the parallel heading with speeds may work. A mistake can be made to reach out too far. Let it develop, and then make the decision. For example, two aircraft converging crossing. I may see this 125 ahead of time. Even if the speeds are such that they are a tie, you can have a jet stream that is across your sector such that one will be greatly speeding up. An error in this area would be not reading the strips properly. They may just read the time and altitude, and not read the route. Also missing wrong altitude for direction is a common error.

Determining most time-critical problem: I don't know if a person consciously determines that this is the next action to take. A lot of it is knowing when you have to act. In working a sector, there will always be a few planes requiring special attention. When do I apply that attention? That depends on the individual. Some will do it early, others late . . . . There is a decision process, but I don't know how to answer this question . . . . I don't think it can be taught out of a book . . . . The obvious one is separation; it should be number one priority. The next should be an orderly flow through the sector. And there will probably be a couple of aircraft that will want direct routings, or reach out and coordinate. Under any traffic situation, there are always several airplanes that need special attention. The key is: When do I want to start that particular solution? In light workloads, experience level is not that great. In heavier workloads, there are a couple of things someone must learn. Once a person is comfortable with volume of traffic, then that decision-making becomes relatively easy. Also familiarity with the area that you are working. . . it all comes into play. Tunnel vision can be a problem in that someone can be looking at a potential and missing the actual.

Determining which action requires minimum coordination: That is an every-hour situation. You can get into subtle things. You can get into technique. There are a couple of things to remember: How busy is the controller who is sitting beside you (the D-Side)? Which action would help him the most? Am I overpenalizing the aircraft? A person has to keep service in mind. Experience, the subtle things would be a little tougher. . . a lot of that is technique.

Determining the most efficient order: That is used constantly. There are a number of variables: Do I have to have 10 miles in trail? Is it in 70 miles or is it in 150 miles? Different techniques would be used. The key variables include: the altitude of the aircraft, the direction of the winds at high altitude, type of equipment. They apply to just about all types of sequencing. Type of equipment comes into play with the greater distance. At altitude it is impossible to keep a slowed-up 747 behind a wide-open 737. Another thing is company policy. Some airlines will not cooperate on accelerating an aircraft for sequencing. Some airlines do not like to descend early. Other airlines climb out at specific speeds. Other carriers go faster as soon as they lift. Some you absorb by being around. Some of the errors here include not knowing the type of equipment or not knowing the winds. The controller may try to start the sequencing process too soon. If it is needed down the line, you wait. Another error is turning the wrong aircraft based on the prevailing winds. Tunnel vision can come into play in that a person has a problem not related to sequencing resulting in sequencing problems (e.g., forgetting to turn the aircraft back).

Determining route with minimum traffic impact: This is not used often. It is not used that much in high altitude since our hands are tied.

Determining if an aircraft can be cleared direct: We do that a lot. Even though we may be able to do it without impacting traffic, sometimes we do not do it because I could put the manual man under, so sometimes we back off during the rushes because it is too heavy a workload for the manual guy. We don't turn down requests, we just don't volunteer it. If they have the equipment, and if flow restrictions allow us to go direct routing, offer it to him. It is providing a service that is used a lot. It is not one of the tough ones. If it is done frequently, the pilots realize that we are doing what we can for them.

Pre-planning (off the strips): We constantly look at strips at high altitude for potential conflictions. We are a pure radar environment, so the old non-radar separation standards apply, but they don't . . . If I have crossing traffic over NAVAID X, one is eastbound and one is northbound at same altitude and tied, I probably would angulate those strips, and let it go at that. When they come on frequency, just vector one around the other. You have to have a general idea of what is coming into your sector. It is relatively easy to see a potential confliction, but the next step—what is he going to do about it?—that is harder. Some of the variables in pre-planning include: where the problem area is if it is across the line. If the workload is busy, I will reach out and resolve it. I think that the biggest factor that comes into play is workload. If you are busy, take care of them in time. You do not want to put your other team member under, so the team concept has to come into play.

Projecting: This is done constantly, and again experience level depends on the situation. A tough situation would be some of the random route flights that B52's make. Long-range, if you have a JFK stream crossing with a Detroit stream, you could give the next controller multiple sets of parallel that are converging at the same altitude. You might want to uncross that stream. We use mostly vectoring, some speeds.

Other strategies: One thing is to let things alone as much as possible. I am talking about still providing a service, but you need the patience to let things work themselves out. You may see trainees worry about things that are 20 minutes away. Wait until you know more about what will happen. You cannot emphasize enough the need to know your own area. You need to know sector traps (the confliction points such as crossing of airways that will get you when you don't expect it). You also need to know about the general type of traffic, the holding fixes, the re-routes that are required for major terminals. If you don't, the next sector may shut the door on you. One of the key things is to stay calm and keep your voice level steady. If you don't, you will get a lot of "say again" requests.

Summary from B07 & B08

Shortcutting: You may look at the short-term advantages without thinking about the long-term effects, and not thinking about what it will do to the next sector.

Letting speed take effect: Someone with experience will be able to project something down the line in a number of minutes and remember to come back to it to check, and have confidence that it will work rather than jump in and start changing. A common error is forgetting to monitor the situation. Another error is selecting speed when something else would be better. Most people use speeds if the planes are going to the same airport—they are going to have to be entrail eventually. That is a good time to use speeds, or they are going to be on the same route for a long distance at the same altitude. In that case, speeds are fine for a distance over 150 miles. As a general rule, we vector to establish sequence and use speed to maintain it unless we are talking about a great distance (over 200 miles). An improper use of speed is in trying to keep a faster aircraft behind a slower aircraft, not understanding the impact on the aircraft given the type of aircraft. Some of the trainees do not have a clue as to what that aircraft can do. They may try to speed one getting to go as fast as he can and then get the one behind him going as slow as he can. When I went through here, they did not teach you all the commercial planes. They taught about the DC-3 and how to recognize the Cherokee. They should group aircraft by characteristics and then teach those characteristics . . . categories like the slower jets, the medium- to high-performance jets, and the heavy jets. We don't see aircraft, we see targets. What they teach down here is aircraft recognition as if you were in a tower. It also is a problem when you present all the characteristics of each aircraft. All you need is about five categories, with less than 10 planes in each . . . what their normal cruise Mach is and associate that with their knots and how they climb.

Early control: The lower the experience level, the more likely you may be to use that. You may reach out to separate two planes that are going to cross in 75 miles. You may think you solved the problem, but what you have done is tied up the lines, and have bothered another sector when you could have done it yourself (when the aircraft entered your own sector). Or it may not have been necessary since the speeds may have changed.

Eliminating a factor: You may have to make a number of decisions before making that action. One problem here results from using insufficient vectors. He may think he has turned him enough to miss the guy but he did not turn him enough and he will have to turn him again. Sometimes the trainee with the least experience will do something that did not have to be done. If you let the planes alone, they may be fine. Or they may tunnel into one aircraft, and they turn him, and there is another airplane for him (or descend him into another aircraft).

Sequence to minimize own workload & Determining the most efficient order (sequencing for service or the next sector): When sequencing, you execute a number of actions and your workload goes up. Sequencing is pretty difficult. Some people will try to work the same sector the same way all the time without realizing that there are winds that affect it or that a couple of simple moves might have made it easier for everyone. They also wait too long to start their plan, or they don't have a plan. Sometimes, the developmental is not doing anything, but his mind is spinning with all the options without saying, "That is what I am going to do." And then make it work. Your plan may not be the best plan, but you select the plan, and then make it work. From all the options, they are not able to select the best. Rather than do something, they just spin there. As a trainee, you may spend as much time trying to figure out what your OJT instructor would do, rather than what you are most comfortable doing.

Determining most time-critical problem (prioritization): This is done constantly. Most of our students have difficulty prioritizing. They don't know what to do first, they go from one thing to another without a plan. Tunnel vision can be a problem, in that you are not re-prioritizing all the time. You don't keep evaluating what is going on. You have to constantly prioritize. One error is allowing the airplanes to dictate your priorities to you. For example, you get so involved in handling pilot requests, such when aircraft are getting bumped around, and they want altitude changes. You are responding to them and you forget what is going on. You allow the airplanes to interfere with you. The military may be calling for a clearance, but you may have to take care of something else first. It is hard to have someone squawking on your frequency. You have to ignore him—a separation problem needs attention right now. Sometimes the trainees will tell you what they are going to do, and when they start, VFR will call them on frequency, and the trainees will start talking to him rather than doing what they said they will do. There are so many variations. Distractions are one of the main things. Everything is a distraction if there is an immediate concern. VFR's calling are a pretty big distraction that can be avoided. You do not have to provide the guy an immediate service. You can just tell him to stand by.

Determining which action requires minimum coordination: Sometimes a trainee may want to try to be the pilot's friend and may go overboard. Why don't you see if we can go through this restricted area, and see if the next sector will approve. Forget it, you don't have time for that. Just leave him on his route. The newer controllers may be too service oriented, and with experience they become less and less. When you come in, you may want to do everything for the pilots, but after a while, you realize that you cannot and you reach a happy medium.

Determining route with minimum traffic impact: If you are re-routing planes through your sector, you have it pretty much down how you are going to route them, standard ways you are going to send them. Trainees tend not to look beyond their sector to determine what impact this will have on the next guy. So that planning beyond your sector can be important.

Determining if an aircraft can be cleared direct: We have direct points where you can and cannot go depending on whether restricted areas are hot or cold. That is the whole decision: Can he go through the restricted area or can't he? There is no room for error in those cases.

Pre-planning (off the strips): Strip search, coordinating the information on the strips with the airplanes. Strips are the first thing that you miss once you start getting busy. One of the main errors is not noticing planes that are coming in at wrong altitude for direction. They may not notice planes that require re-routing. They look at the strips, but they don't acquire the information, and they don't project out onto the display. You have to be able to develop a picture in your mind. You look at everything on there to make sure that everything is correct. Redundancy is the primary thing, you have got to constantly update. The biggest thing is to get the trainee to look at the information on the strip, and be able to pick out what is wrong with it. Some people use marking tools, like westbounders get some marking, and eastbounders get another marking. I don't use it, but it is there as a tool for pre-planning. A lot of it is sector-specific knowledge. The way that the airspace is designed is going to determine which way your conflictions are normally, and that determines your traffic search on your scope and also on the strips. You will have the same crossing problems.

Projecting: Like with sequencing, some people may not take the wind into account. Sometimes they may not take speeds into account. Sometimes they may focus on solving a conflict, failing to project where the guy will end up based on the conflict solution. Maybe later they realize that they have another confliction because of the action that they took. Some people project too far out, looking at someone 200 miles away.

Other strategies: One strategy is to determine what action I can do to solve several things (determining optional action). Consider other options. Following through with readbacks or correlating information with what you planned. With experience, you get improved anticipation, and you are likely to become less service-oriented. Determining optimal actions is something that can be done by putting all the factors together and using all the tools that you have to come out with the one decision that is the best. At times there is not an optimal action.

If I see a trainee do the same thing over and over again where there may be three ways to get it done, I might ask him to pick one of the other two and try that. Once he is doing that well, then he tries something else. Now that he knows three ways to handle a situation, then I will let him pick the way that he wants to do it. Then he has his own technique. He finds out that this one works a little better in this situation, but when he is busy, he will do this because it is easiest. We try to break them of the habit of doing the same thing. Be flexible and understand that you have to remain that way. In teaching you are rewarded in being consistent (may be a problem with the training approach).

In the discussion of types of problems, one of the controllers agreed that there are probably prototypical controller problems. They try to teach you the basic situations that you will come upon. Like a sequencing problem, traffic crossing at the same altitude...you can take care of it the same way. Climbing traffic, descending traffic, head-on climbing traffic.

I try to get traffic through my sector as fast as possible. Like on the re-routing, it is going to get him out of my sector faster. If it is not a problem for anyone else, I am going to do it. I have gotten rid of one guy, now I can take care of another. Using speed controls, rather than slowing down the back one, I will speed up the first one . . . get them both going fast and out of here. I like to take care of the little things so the big things don't get to be a problem. I don't wait for an optimum time, I get it done. That way I have time for other things if things develop. It is just keeping ahead of things, rather than letting the plan run itself. Don't wait ten minutes, do it now. Otherwise, you will get busy with something else and forget about it.

Many errors happen after you have been busy, and things have quieted down, and you may just have a few airplanes, but you let your attention down.

APPENDIX D: RETROSPECTIVE PROTOCOLS OF DYSIM OVERLOAD PROBLEM SOLVING

Work Overload Retrospective Protocol: PERFE, B01-2/12/91

0:00 - 7:24 Sequence

INTERVIEWER: Okay, so now we're running again. This is Controller B01. The time is 12:43, and we're going through the reconstruction of the mission.

CONTROLLER: 432FM I noticed was going into my vicinity via a very nondirect route, so I just gave him direct. There was nobody out there. There was no reason not to. This guy was a departure.

What I would do then is try to figure out who he is and where he wants to go because I'm not real familiar with going to Kansas City up that way.

It was right around in there that I noticed there was an area of weather, which I think I gave him a little bit down the line. There was no traffic for him, so he climbed to 13.

And this guy flashed, and again, I need to find out where he wants to go and what needs to be done with him. At first I saw the two Xrays and got them confused with this guy, first and second, and realized he was going to Kansas City. I wasn't sure from the way the strip was written whether he was really going direct or not. I think that he was and they just had to use this for a computer fix to get it to buy it. So just to make sure, I cleared him direct to Kansas City because, again, there's no reason not to.

INTERVIEWER: Okay. And that's 425X?

CONTROLLER: 425X, right.

So at this point there's not really too much going on.

Again, though, a lot of what's going to happen here is trying to figure out where in this sector an airplane wants to go and what, if anything, needs to be done to them. And the only way I'm going to get that information today is off the strips or possibly a flight plan readout, which doesn't help me a whole lot. The QU, or the route readout, which I'm doing from time to time here, will help me a little bit more. And this guy is an overflight, I believe.

INTERVIEWER: Okay. That's 632 Y?

CONTROLLER: 632 Y. Let's see if I can find him somewhere. I don't know if I pulled some of these strips down or not. Here he is. He's the slow guy going eastbound. He's going to stay at 7,000. And I know, for later on, that if I go into McAlester with arrivals, I may have to miss this guy at some point. I just make an awareness note that he's out there.

What I'll do in the real world sometimes is I'll slant two or slant three of these lines as an awareness check, which in the old days translated from moving these "shrimp boats" when the scopes were flat, and you would constantly update yourself. Well, that was lost when they came up with these PVD's. The way I carried that over is I'd "dink" around with the data block from time to time, just move it around, north, south, west, or east or something. I mean, it's just a mind thing that keeps you aware of what's going on so you don't forget that certain guys are out there. You used to have your hands physically on these guys to move them along, and that hand movement would really keep you aware of guys that are out there. So I've always carried that over and I still do that.

I got a call from this VFR 57 X. In the real world, I probably wouldn't have a strip on him. So I told him to maintain VFR and I'd get back to him. And I got a Cactus wanting to go to Oklahoma City, Cactus 45, that called from radio, which means I had to issue a full clearance although I don't think I've ever worked with a radio before, and a clearance void time and that whole thing.

I'm trying to remember what I gave him. I guess I gave 4,000—or 7,000. He was at a 4 when he came over. I gave him 7 for starters simply because I didn't know what I was going to do with this guy. I don't really know where Oklahoma City is. So thinking this guy was at 8,500 or something, I stopped him at 7, which is strict nonradar 1,000 feet, knowing that I'm going to clear this guy to some altitude later on.

And I gave this guy a 30-degree turn for identification as 57 X and identified him out there. He came over requesting vectors around the weather. Under normal circumstances, as busy as it got, I probably would have terminated this guy. The fact that all this weather was out there, I wasn't going to terminate him. I considered him just as high priority as everybody else.

87742, the Air Evac, DC-9 overflight to Amarillo, he's just going to right across here. So he really wasn't too much of a factor. There's nobody else in a problem at 16 right now. So I can take the handoff on him with not too much worry.

So I went ahead and either go through the secretarial work at starting a track on 57 Xray telling him to maintain VFR again because you never know what they're going to do out there, and then eventually give him a heading around the weather.

This Brash 55 flashing at us, landed all the way down here at McAlester, I knew I had plenty of time to do whatever it was I needed to do with him. At this point in the problem, I wasn't real concerned about him.

I notice the Cactus coming off. He's got traffic out here at 13 going in the opposite direction. I could probably turn this Cactus west and climb him, but I'm thinking, what can I do in the flight service area? I could probably do anything I want out there, but not really knowing, it didn't really matter. He's going to have to go through all these altitudes before he gets to 12 anyhow, so I just let him go on course.

There's no real pressing need to do that in this case. He's going to blow by that 68412.

The same thing with this guy going the same way. He's a Lear, going to be behind the Cactus. He's not really a problem going out to. Now that I know where Oklahoma City is, I can probably go to 12, which I think I did. This American 27 that I took the handoff down here, lands at Tulsa and he's not really going to be together with anybody but this Fox Mike if I choose to leave him up. So what I did was as soon as he came over I started him down to some clean altitude. Where is my strip on him? American 27 up there.

I'm a little bit concerned about these two, 25 Xray and American 27, because of speed overtake. I'm not really familiar about what route this guy is going to fly, this American 27. I didn't want him running up his rear end either, so . . . . Now, this is something you would not necessarily see in real life because to look out here when 31 Bravo Golf flashed at me—and he's wired with this American 27. In real life, the D-side would separate those two hopefully before they came over or you could bounce the D-side into the next row. So when this guy comes over, I dumped him immediately. He's going to obviously be a factor for 25 Xray and the American.

INTERVIEWER: Okay. That's 31 Bravo Golf.

CONTROLLER: 31BG, yeah. And that's just something you wouldn't ordinarily see.

But that's an example of air traffic reacting. Hopefully, through everything they're trying to do here, we'll get away from it; where a D-side or a manual controller would see this well before this situation ever developed.

7:24 Minute Freeze

INTERVIEWER: Okay. We're frozen at 7 minutes, 24 seconds, into the problem now.

CONTROLLER: Okay.

INTERVIEWER: Thank you. So what we want to do at this point is describe as best you can recall what happens over the next minute in the sector, just by giving me important information on any particular aircraft, what part of a plan you have and/or you're executing, or any specific task you worked on or strategies you employed, as detailed as possible and just making sure you mention all the decisions that you made or as much as you can remember about them, managing that timeframe.

CONTROLLER: Okay. The first thing, the first priority is this 31 Bravo Golf, number one. He's wired with 25 Xray. And I'm trying to think of an altitude to take him to. I don't necessarily want to take him out of the problem and have to go through all that coordination with a sector that doesn't know anything about him, which will slow me down even more. The fastest way to get him clean of 25 Xray is to descend him. He's going to descend faster than he's going to do anything else. I thought about moving 25 Xray, but he is a G1. He is neither going to climb or descend as fast as this 31BG. So he's the airplane I decided to move, 31 Bravo Golf, because this is what I consider an imminent situation.

INTERVIEWER: I see.

CONTROLLER: So given the fact that it's an imminent situation, I'm going to get separation the fastest way possible, and that was to start 31 Bravo Golf down. And if I didn't see him go down immediately, then 25 X would have gone up also, so that you had it working in both directions. I know American 27 needs to start down. He is still a factor for 31 Bravo Golf who I'm going to take down the 21. I could take him to 20, which is the right altitude for direction, but I didn't because I knew I'm going to have to get American 27 under him anyhow. So why go down and make that situation any harder than it already is going to be or may not be, because I'm not really sure how far apart these guys really are because of the range that we're on. So I just went to 21 thinking that I could either go back to 22 when the situation resolved or go down to 20 or APREC him at 21, which is the wrong altitude for direction. There's no problem in doing that. So I was going to start American 27 down to 13, which is a clean altitude as far as Fox Mike being in there. They're so far apart at this point, I'm going to get a very good idea how he's descending and if later on I need to turn him to miss this Fox Mike, or restrict him—and miss this Fox Mike—well, I can do so. Or if he goes down really nice for me, then I can just descend him underneath. I know that I've got this VFR on a 180 heading and that I'm going to have to turn back.

INTERVIEWER: That's 257 X?

CONTROLLER: 257 X. I don't want to leave him on a 180 heading forever. That's a suggested heading. I've got the Cactus coming off here. I'm going to have somebody coming off right behind him going the same way. And the Brash, I still have plenty of time to deal with him. And when I do start him down, it will be to some altitude, not necessarily my lowest available, but just to get him started down for no other reason than that.

INTERVIEWER: How do you know you've got plenty of time to work with him?

CONTROLLER: Well, he's going all the way down here and they're landing to the north, so since he's going all the way to the southern part of my sector, then I'm going to have to vector him around back to the north. You know, I can leave him out of my hair as long as possible. I know I'm going to have to descend him out of the high altitude so they don't have to watch him forever. But they are watching him and, you know, if I want to leave him at 24 for a while, I can do that. That's about it.

INTERVIEWER: Okay. Let's go ahead and start again and see what happens. Ready?

CONTROLLER: I go down the "shitter," that's what happens.

7:24 - 9:15 Sequence

INTERVIEWER: Okay, we're running again. So just describe to me again what's happening in the situation.

CONTROLLER: Well, this 31BG has thrown me out of the chair.

You'd better put that on pause. We're a little bit behind it here.

INTERVIEWER: Okay.

CONTROLLER: Wait until that Hotel-Hotel pops up.

INTERVIEWER: Yeah, that's right. You made the—just as it came up.

CONTROLLER: And I start this Brash down to 16 mainly to keep him out so the high altitude doesn't have to watch him. There's no real rush for him to get down. There's no real traffic. Knowing how these problems work, if I went to 13, which is really what I have right now, he'd probably go all the way down to 13 and get my problem down there. I don't really need that. In real life, I'd give him a PD, probably a PD clearance. I know he's going to be a factor—a possible factor—for this Cactus 45 and whoever is coming out behind him, that Hotel-Hotel. So, again, that's another split-the-difference type altitude. If they do become a factor down here and I do need to get into vectoring, I can still climb the Cactus to a reasonable altitude, and I've got him descending to a reasonable altitude where I'm not going to get stuck up down here. That was the choice of 16. This down here, I'm starting to get busy . . . . There's the Hotel-Hotel popped up. He's climbing a 12—1-2 thousand—again reference the 13 northbound.

This is a problem here that the next sector is handing me a deal basically, in that the Delta is eating up the American. Rather than get real fine about it, I just slow the Delta to 250, which I know is going to at least keep what I got, depending on what American is doing, which I'm not really concerned about. So, slow the Delta 269 to 250. I know that's going to give me separation. And start him down to 13 also.

Same thinking for the Delta as for the American 27.

9:15 Minute Freeze

INTERVIEWER: All right. We're frozen again at the second point, in the second freeze point.

CONTROLLER: Okay.

INTERVIEWER: So, again, describe to me what's going to happen over the next minute.

CONTROLLER: Okay. Well, I know that I've got Cactus and Hotel-Hotel climbing to 12, because it was 13. I certainly don't want to forget about them out there because if I leave them on vectors, whatever, this is not a good idea to have guys pointed at each other at the same altitude even though they're pretty well separated, Hotel-Hotel possibly with Fox Mike. So I'm going to be watching this situation. I'm also watching the Brash 55 situation and it's looking more and more like I'm going 15 only, until I see how this situation is going to develop. And I think later on I do turn the Brash a little bit to the east to get him behind this Cactus so I can climb the Cactus. Hotel-Hotel is low enough where I'm not really going to make a decision on that right now. I'm not really sure how that's going to look. He's going to speed up when he gets out of 10. It's kind of hard to make a decision based on what you're seeing right there. And I know I've got the altitude here and I'm clean. Now I've got the Delta slowed to 250. He's probably not going to come down very well at that speed, so I'm concerned about getting him underneath Fox Mike. And that's about all that's happened.

The Air Evac asked for vectors around the weather and I turned him north. And that's just something else. All that is, is just kind of a pain in the butt. You're going to have to watch him so you don't leave him on the heading to get out into somebody else's airspace and violate somebody's boundary out there.

And that's just an awareness thing. That's, again, as I explained earlier, I think I slant—you can see I slant two to him. See how much longer the—

INTERVIEWER: That leader is?

CONTROLLER: —the leader line is. Just that's how I connect with what's—I've got something cooking out there. I just try to stay in touch with it that way.

INTERVIEWER: I see. So that's why you put the longer leader line on him.

CONTROLLER: Uh-huh. Exactly.

9:15 - 10:30 Sequence

INTERVIEWER: Okay. We're ready to go again. We're rolling again.

Please keep talking.

CONTROLLER: There's another. This guy wants to hold out there.

That's another thing. Probably in real life, knowing what I know now, I would end up holding him out here somewhere. I'd make up a fix, pick out a fix, something, rather than hold him at this VOR. I think what I did is held him east simply because I didn't really realize how much stuff we were going to get into out here to the east of the VOR. When I did, I think I changed it to have him out to the west. And if that ever happened again, now having done that and seeing how the traffic flows, I would hold him out to the west or southwest just to keep him out of my hair.

I'm trying to figure out who the Continental is and I see the American—Continental 56 and American 33. I realize I got two inbounds wired. I make a decision right off the bat as to who's first.

INTERVIEWER: How do you do that?

CONTROLLER: At this point, you just pick one. It doesn't matter. It looked to me like the Continental was a little bit closer, so I think I gave him 320 or better; and the American 33, at that point I just slowed to 250 because they're that wired and I don't have very much room out here to work with. The Bandit, I got a handoff on the Bandit 8 and I realize he was not really a factor. He was just going to fly from the sector somewhere going to McAlester or somewhere down here.

10:30 Minute Freeze

INTERVIEWER: We're frozen again at 10:30.

CONTROLLER: Okay. Now, I know from what I saw earlier with this Continental 56 and American 33, that if they start flashing me more guys out of here, I'm done; which, of course, they did.

INTERVIEWER: How do you know that?

CONTROLLER: Because these guys are wired to begin with. They're tied to begin with. In order for this situation to work, I'm going to have to open up 10 miles between Continental 56 and American 33. If anybody else comes over wired, I'm going to have to open up 10 miles between American 33 and that guy, et cetera. To get 10 miles between these aircraft in that short a period of time is dang near impossible without doing north-south vectors, very heavy vectors, maybe even spinning the guy. This is really not a workable situation when they start handing you three and four guys on top of each other out here. You need to get them in trail. The best thing to do is to go into the hold. Again, I'm looking down here. I see American 27 is not going to be any problem at all getting underneath Fox Mike. I still don't know about the Delta. I do need to go to 11,000 with these guys and that's all I need to ensure.

INTERVIEWER: How do you know that American 27 is going to get under Fox Mike?

CONTROLLER: His rate of descent through here.

INTERVIEWER: Okay.

CONTROLLER: Now, this is one of the hardest things we have with new people, is when can you "bet on the common one" catching? Well, first of all, this aircraft is 5 miles south of the—is "at" the place—I'm sorry—where American 27 is going to over approach now. Even at 180 knots, which is 3 miles a minute, he's going to be west of that airway. He's not going to be a factor laterally, most likely, unless something happens out here. What I like to do it is positively separate the guys. I'm going to base it more on the altitude. In the way American 27 is coming down, unless he does something very drastic, he's going to be well underneath this guy if I go to 11,000 feet with his present rate of descent. Now, if their proximity was a lot closer, that would be a different story.

I also have Plan B, in that if it doesn't look good, I can just vector the American around the backside of him. The same with the Delta, if I need to. But I'm not going to get into that if I don't have to. That's just one more thing to worry about. And I've already got 57 Xray out in the heading, I've got the Air Evac on the heading getting dangerously close to somebody's airspace out there, and I'm worried about Brash 55 and getting the Cactus through him, and also Hotel-Hotel. And now they're flashing me these two inbounds that are wired out here. If I don't have to "dink" around with these two guys out here, I'm not going to do it, so I'm just keeping a close eye on it. And that's what I'm looking at right now.

10:30 - 11:30 Sequence

INTERVIEWER: Okay. Let's go again.

We're running again. So tell me about the situation now.

CONTROLLER: Okay. Well, I've got Continental 56 that I'm going to try to make number one.

I've got American 33 out here.

I just turned the Air Evac back so he doesn't get into somebody else's airspace.

And I make a decision here: He's number one, 320 or greater. Just let him rip.

Now, I'm not real familiar with exactly what's he's going to fly out here either. It looks like he's going to come around the backside of the weather, so I'm not too concerned about that. Now I see United out here, and he's about 4 miles behind this guy. I can't see the speed on him on Delta, and I know I'm shit out of business. I can probably get United in trail but there's no place for the Delta. And when they put Southwest on there, there's no place else to go. We're done right here and there. If this were real life, Delta would be spinning, Southwest would probably make one turn also and not even come in my airspace.

11:30 Minute Freeze

And this is right here. If I have to work these airplanes—there's no way for me to control what's going on out here—I'm done.

I'm basically shooting for altitude and hoping like hell I'll eventually vector these guys in trail. But that's all I can hope for, and I know it's pretty complicated because I've got this 22 overflight going north from here who is going to be a factor with United. So he can be a factor with everybody that I've got to dump through him, but I think what I'm trying to do first of all is miss the overtraffic. By doing that, I'm leaving him an altitude for a while, I'm changing United 89's altitude, and I'm going to dive through him with whoever else I can to start with. He's still got a few minutes to get up there, but with the vector that I'm going to be doing, he's going to be a factor with everybody in there. It's probably not a good place to put a guy knowing we're going to have an inbound rush, which I now know; but at the time, there was nobody out there. There was no reason not for him to be there. When I see all these inbound strips popping out, I may just vector this 25 Xray next time right over the airport and up that way, and he's not a factor for anybody out there.

That's about it. But I know at this point I have one—what is it now? American and Continental are wired. Southwest, United 89, and Delta 12 are wired, in my mind at least, not knowing exactly how they're going to fly out here. There's three—one, two, three, four, five airplanes that all need to be put in trail with each other. And there's really nothing to be done because the second airplane in the rush has already slowed to 250 in order to get the first two guys separated. So you're done there.

INTERVIEWER: Okay. All right. Let's go.

11:30 - 14:00 Sequence

CONTROLLER: You can also see here I'm turning this Brash 55 to go ahead and climb the Cactus and get him out of my hair. And I went to 15 with Hotel-Hotel.

INTERVIEWER: Keep talking. Tell me what's going on in your mind.

CONTROLLER: You know, I think at this point I was just befuddled with all the inbounds over here, and really trying to come up with a plan to deal with the back four guys—one, two, three—or the back three guys, because there wasn't any place to put them. At that point, they punched off United 41 that I knew was going right into the face of all this vectoring I'm going to do out here, and there's really not much to do there except go to altitude.

The 377, I'm not even sure I remember him. I don't think I took the handoff on him. I was trying to tell the next sector he was in the hole, because at that point I was just saturated.

INTERVIEWER: 377?

CONTROLLER: I have the Cactus climbing right at him. I'm going to have Hotel-Hotel climbing right at him. I don't really know where he's going. I don't need that airplane at that point. I went to 11 with American 27. He's now a factor; the same with the Delta. There's not going to be a factor with 432FM. So this is actually the easiest part of the problem out here right now. So I've got Continental out here. Now I'm going to look to see who I can dive him through and how I'm going to be as far as in relation to 425 Xray. I know I've got United climbing at him. I've got to get the Brash turned back to the south so he doesn't end up in the middle of this whole fiasco. It's just basically trying to figure out what to do with five inbounds when they all came over together.

You really can't go in any logical order with that. You're just calling shots. This guy is going to follow this guy going to follow that guy. And because Continental is my number one guy, American is my number two guy, I'm just starting to get some kind of separation between them now. I've got no place for United 89, no place for Delta 12. I think I spun the Southwest. I told him to do a 360. Now I can maybe open up some room with these two, and hopefully with some kind of speed and vectoring out here, it will go one, two, three, four, five. And that was kind of my plan.

Totally absorbed by this thing. If it were real life and I had to vector these guys, this would cause me tunnel vision. Well, I didn't do that, I just made sure that they were separated by altitude.

At this point, it would have been nice to shut off all the departures. That would have probably helped.

INTERVIEWER: No, still not stopped—there we go.

14:00 Minute Freeze

CONTROLLER: There we go. Having these two departures coming out here was kind of not what we needed at that point. This is really nothing to do. I've got Continental who's just like—you can just sort of see 49320. I don't even know if the Delta slowed. He's running over everybody. I know I've got United slowed out here. He's together with 25 Xray. I know I'm concerned about that situation. What I ended up doing, as you'll see when it starts up, is spinning the Southwest and going to altitudes with these three and hoping for the best.

United 89—

INTERVIEWER: Okay. Tell me a little bit about going to altitude or how you do that or how you decided to do that.

CONTROLLER: Well, these guys got to go down since they're inbound. So United, I think, went down. And I think the Delta went to 23 after he went down. The Southwest I spun out of there. And now there's another guy flashing at me that there's no place for him to fit because I haven't even opened up all this yet. Again, at that point, if this were the real world, I'm not taking these handoffs. I'm not working these airplanes. I'm going to maintain control of this sector without shutting the whole world off. There's no reason why we should be taking inbounds sequenced the way these guys were. That's just an unworkable situation. So what I would have done is taken the first two, maybe the first three, and had them spin the rest and take them when I can. I believe I tried to do that. I tried to say whoever has Delta 12, spin him. And that's what I would do in real life. I did notice them spinning the three out here, which I thought was very nice of them because I wasn't taking that guy into the sector reference the two departures coming out, Hotel-Hotel and the Cactus. I figured one spin wasn't going to hurt him.

INTERVIEWER: Okay.

14:00 - 17:00 Sequence

CONTROLLER: So here comes United 41 and the Southwest off of Tulsa both going up this way.

And I went down to 23. I already had United 89 going down to something; I don't have it in the machine yet.

And then I went to 23 because I knew it was safe, safe, safe, safe. Okay? It's strict nonradar altitude separation—worry about who's going to follow who next.

I turned the Brash back south so he didn't end up in this whole thing. It's going to mean Hotel-Hotel is stuck at 15 for a while, which didn't bother me a whole lot at this point.

I know I'm clean down here.

One 3,000 for the Southwest is with respect Bandit 8.

INTERVIEWER: I see.

CONTROLLER: I gave the Continental 56 direct, rather than make him go any further south, just to keep him number one and out in front of American 33.

And it was the Southwest Macon 360 out there. Of course, now he's going to be tied with Delta 711. I'm not even sure where he was going. I figured he was another inbound since he came the same way. And—no, he was an overflight. He was not even the problem, but he got 250 and he got sequenced.

If it was an American pilot, he'd probably say something; but if it was United, he'd go right the sequence, get his gear down and say, hey, do I really have to land here?

See, here is another situation you wouldn't see in—both of these guys are overflights, this Continental 84 and Delta 711—100 and something knots on the back guy and somebody's handing you a deal, you know, it's just against ATP. You know, they wouldn't normally do that.

But what I would do in that case is not take the handoff on the second aircraft unless they called and told me what their plan was there.

I'm going to change the Bravo Golf holding to keep him west. Too much stuff going on. I'm going to be vectoring north and south out here and I didn't want him anywhere near it.

And United 41 was climbing to 19. I think the Southwest we ended up holding at 19 also, which was reference to Delta 711 and the Continental 84, which I knew was safe at this point. Worry about getting them higher later.

17:00 Minute Freeze

INTERVIEWER: Okay. We're frozen at 17 minutes.

CONTROLLER: Southwest is spinning.

INTERVIEWER: Tell me, as exactly as you can, what you recall happening in the next minute or what's going to happen in the next minute as we start.

CONTROLLER: We didn't get too much further in this problem, I'll tell that. I know I climbed 282 Hotel-Hotel. I got rid of him. I turned over the American 27. I turned over the Delta. I think I even turned over the Continental to Approach Control . . . I'm still fighting out here for separation. I got the 22 in here, who's clean so far with everybody. I haven't dumped anybody through him.

INTERVIEWER: That's 425 Xray?

CONTROLLER: 425 Xray. But I'm just barely now getting 10 miles—what I'm used to 10 miles, which may not be on this scope—American 56 and the American 33. United 89 I'm figuring I can vector down to the south. The Delta and the Southwest I haven't decided yet, and I probably got in my mind the Delta 711 is in the problem somehow also. So slowing this guy to 250 did not help that situation at all. He came over slower than the back guy to begin with and I ended up slowing him to 250, which makes it even worse, thinking that he's in the problem. That's a very good example of being down the shitter is when you can't find the strips, you don't where the guy is going, and you think he's in this inbound problem and actually he's an overflight and you're just making yourself a problem that doesn't exist. So that's a real good example of that.

That's about it.

17:00 - 20:00 Sequence

INTERVIEWER: One more time.

Okay, the problem's running.

CONTROLLER: Okay. End up with tons of separation out here with Delta, more than you need. That's not something you would see in real life because when you slow this Delta to 250, he's not going to come down like that. Because he stays higher, he's going to stay closer.

But it's not hurting anything, that's for sure.

And the Continental 84, when he came over . . . which took on kind of life for—84—somebody was very nice and slowed him to 250 also. I might have done it, but I didn't mark the strip. That's the only reason those two guys went together. I believe I turned them to the northwest when I saw this kind of turn taken by the Delta 711. It was so sharp. And again, that's something you won't see in real life. Just to make sure I kept my 5 miles, I turned the Continental to the north.

But the biggest factor in here is including these guys in the inbound problem.

It would have been less busy, although it certainly was plenty screwed up anyhow.

Delta is still going north, and Southwest is going south. I'm just now going to figure out what to do with United 89 and maybe vector him behind American 83. And it's just going to be later on before I decide what to do with the Delta and the Southwest as to who's first. All I'm doing at that point is keeping them separated.

INTERVIEWER: Keep talking. What are you thinking about now?

CONTROLLER: I'm just—I know I can get rid of some of these airplanes finally and try to make some sense out of what's going on and get rid of some of the aircraft about the boundary. I wasn't really sure how this was working with the handoffs. Our guys are automatically going to flash at the next sector, so I was just kind of assuming that was supposed to be happening. But maybe it wasn't. The Air Evac was left on a heading up there.

Started the Brash 55 down in plenty of time to vector him on, on the south side. And I got massive data block overlap over here.

Now I'm at 19 with the departure and 20 with the Delta who, like it or not, he's going to land at Tulsa.

INTERVIEWER: At least he's clean. Okay.

So as you are sitting at this point, what was your next priority or what was your—

CONTROLLER: Well, I've got two priorities. I need to get the departures up and out of the problem and I need to get the rest of the inbounds in. But there's not much I can do right now except let them fly, until they open up some room between American 33 and United out there. And it looks like United has even blown by the American. How that happened I don't know, because they were all at 250. But there's nothing you can really do. You're waiting for room to open up, which is why it would have just been better off to leave them out there spinning at a fix. It gets you room right away and you don't end up going down the shitter doing it.

And that's about it.

INTERVIEWER: Very good. Very good. I think that was real useful.

(End of Tape B01 interview.)

Work Overload Retrospective Protocol: PERFE, B05-2/14/91

0:00 - 7:25 Sequence

INTERVIEWER: Okay. Now, I hope we're relatively in sync. So just go ahead and tell me what's going on in the sector, and we'll see—

CONTROLLER: Well, the sector is slow. I'm picking up limited data blocks. This gentleman over here, November 6632 Yankee, is no factor. I'm taking the handoff, of course. I know there's a VFR in the problem.

Okay. We pick up the problem after the freeze. 425 Xray 220 heading northbound. Still there's no problem.

Just kind of coasting at this point. There's not much going on. The gentleman to the north, 68412, I noticed was not climbing. For some reason, I thought he was going to 13. I don't know why I thought that he was; he wasn't. In fact, I'll be honest, I'm not quite sure that he ever does. But I should have climbed him initially. I don't know what I was thinking at the time. There's no traffic for him.

The weather I'm not really taking into account right now. There is weather northeast of Tulsa.

Seven thousand, shooting across. I see things now, obviously, that I didn't see before.

At this point, I realize—32 Foxtrot Mike, I mentioned earlier I don't remember him checking in. I wasn't sure if he was supposed to be on frequency or what the story was.

32 Yankee is going to clear the warning area, the restricted area there, so he's not really a factor at 7,000.

Once again, no problems.

Okay. I'm looking for the guy.

I was trying to start a track on him at the VFR. I never did get it started. I'm not really sure what I was doing wrong, or if I just wasn't hitting with the trackball. I just don't know what happened. I never did start it. I know that he was asking for vectors around the weather. There's obviously weather at his twelve o'clock. And I intended on doing it, but I just got too busy and I forgot about him. It's a secondary . . . responsibility.

The line continues to ring because I'm trying to start the track. I don't want to get behind at this point. And I never did start it.

Looking for the strip over in the departure bay.

INTERVIEWER: Okay. Very good.

CONTROLLER: Once again, I should have climbed 68412. That would have made it easier for the Cactus. Didn't do it. So, obviously, there's traffic at 10 climbing to 9, which is a safe altitude.

I should have been taking handoffs on the Air Evac. In a real-life situation, they would have kept him clear of my airspace. Now, of course, they're going to keep coming.

INTERVIEWER: Can you recall what you were doing here?

CONTROLLER: At this point I was still a bit concerned about the track on the VFR. I probably shouldn't have been. In retrospect, I probably—I might have refused VFR flight following because, like I said, it's not a requirement. Had I to do it over again, I would have done that—since I got hung up on the track and I just, I devoted too much time.

Everything is pretty much separated.

I've got two 22's, 425 Xray, and 31 Bravo Golf coming together. I—

INTERVIEWER: We just lost our display.

For some reason it's frozen at six-twenty and your targets were still moving, but the clock was frozen at six-twenty. It went right past seven-something. So I'll freeze it at 25 seconds here.

Right, right.

CONTROLLER: My concern now is separation. I see the two 22's, 425 Xray, and 31 Bravo Golf. I feel I've got enough time to dump through on Bravo Golf when I get him. I believe that's the lander in this thing going into—yeah, he does. So I'm not real concerned about that. They're not real fast.

7:25 Minute Freeze

INTERVIEWER: We're frozen now at 7:26. That's good. That's just the kind of description I need.

Now, just summarize everything that's going on in the sector for me right now.

CONTROLLER: At this point I feel that I've got control of it. As I see it now, there are a couple of things that I should have been doing.

But I know that Brash is going down to McAlester. I see my two 22's that are traffic. I'm not really all that concerned right now. I know that I haven't started track the VFR. It's my intent to just not waste any more time doing it. I've already wasted too much time. I had to track them across there visually. I'm sure that goes down the drain later on, but right now it's my intent. Like I say, I'm not really all that concerned at this point. Things are running relatively smooth.

7:25 - 9:15 Sequence

INTERVIEWER: What are you thinking about now?

CONTROLLER: Well, I'm looking for the strip.

My phraseology is just so outdated here. I'm not really quite sure if I'm even issuing him a legal clearance.

Okay. In actuality, the Bravo Golf was in fact in my airspace when I dumped him down to 8,000. I was concerned about that. I didn't want to violate someone else's airspace. That's the traffic at 22.

I still feel relatively comfortable with what's going on. I've solved the traffic problem. I'm starting to get a bit behind here with the departures out. I should be getting these guys up coming from Miami southbound, and I'm not doing that.

I'm turning the guy for the approach to the south so I can line him up from the south.

Everything is—

9:15 Minute Freeze

INTERVIEWER: We're frozen again now at—oh, we're not frozen. Now we're frozen. Once again, let's just summarize what's going on in the sector.

CONTROLLER: The traffic is starting to build. I probably—in a real-life situation I would have probably had help around this point, certainly at D-side. My concern is to get all these peripheral responsibilities away from me—answering approach, which a D-side can certainly do. I shouldn't be taking those approach calls at this level. I should start concentrating more on separation, and I'm just getting pulled away from it a bit too much. I'm starting to feel a bit uncomfortable with the sector. I start seeing things . . . a bit too late. The Cactus 45 coming up on the approach airspace—I believe I saw that, but I should have seen it before I did. So, once again, I should have climbed 68412. He's kind of being a pain there, and I should have gotten rid of him a long time ago. I think I still—I feel that I have a pretty good understanding of what's going on at this point. Things haven't gotten out of hand. But I would have had help.

INTERVIEWER: Tell me, as best you can recall, what happens in the next minute, what you were doing in the next minute of the problem.

CONTROLLER: Specifics, I can't really say that—what I was doing is worrying about setting up a couple of these approaches now. Bravo Golf I've turned towards the approach. I realize that Brash is going in. I'm still thinking about that now.

I don't remember specifically thinking of anything else.

INTERVIEWER: What would you have imagine was your first action as the problem started up again, and why would you be doing that?

CONTROLLER: I don't know. Looking at it now, possibly being concerned with Cactus with approach. I've given up on the VFR. I'm not sure, specifically, what I did next.

9:15 - 10:30 Sequence

INTERVIEWER: Just keep talking about what happened.

CONTROLLER: Okay. I'm concerned about speech rate, trying to keep speech rate low.

Okay. When Brash asked for a straight-in approach, to be quite honest, I wasn't sure he could do that.

I just picked an interim altitude, just an altitude to get him out of the high-altitude stratum.

I clear Bravo Golf to hold, and I notice at that point that he's heading east—southeast—and that throws me a bit. I'm not quite sure what he's doing there. I question it later on. I should have questioned it before.

10:30 Minute Freeze

INTERVIEWER: We're frozen again at 10:30. You were saying you questioned that later on because it didn't seem to be proceeding direct to the fix?

CONTROLLER: Yeah. I'm not quite sure what he's doing, and I'm being distracted by that. And at this point I'm starting to get into what is probably a serious overload problem. I'd have had management involved by now, certainly. In a real-life situation, I would probably have asked for some in-trail, but I expect that they're going to do that once they see that I've got a problem. I would expect, at this point, for management to see that I've got a problem here.

INTERVIEWER: Okay. That's very good.

CONTROLLER: And I don't feel that I—

INTERVIEWER: What are some of the signs of that right now that you'd expect them to see or that are occurring to you?

CONTROLLER: Sheer volume, for one. I'm starting to get on taking handoffs. I'm just not providing the service that I should providing. I gave this Brash 20,000 feet even though there was really no traffic. I could have taken him considerably lower than that. Bu I'm starting to get into the desperation moves now because I'm just trying to get guys down and out of—because I need to get them out of the high altitude stratum, I know that. I should still be giving them really concrete altitudes, like really meaningful altitudes, two-zeros-zeros is not. It's just kind of a stopgap type thing. I'm starting to scramble now, stopgap, and just trying to—but I'm concentrating on separation, and I still don't really have any separation problems.

Cactus, I'm getting up. Approach is watching him. I've already taken care of that. So I'm falling behind, but I'm concentrating pretty much now on trying to keep airplanes separated, and I'm starting to get into serious trouble.

INTERVIEWER: When the problem starts up again, what do you recall as the next thing you were doing here?

CONTROLLER: I think I'm starting the course about Bravo Golf here in the near future. I'm still not quite clear on Brash 55. That's a procedural problem. Once again, I didn't know that he could shoot her straight-in from the north. I think I quizzed somebody across the room on that. My concern now—I'm getting toward where I'm just concerned about keeping airplanes separated. Even if it's a total fiasco, if I get them over the airport at 24,000 feet, they're still separated, and my main concern right now is separation.

INTERVIEWER: Very good.

10:30 - 11:30 Sequence

CONTROLLER: So I'm not making entries. I've given the Cactus higher, and I have not put it in the machine. I think I'm probably doing the mechanics of that right now.

All I'm doing right now is just talking with airplanes. I'm not marking strips.

I've also given the Cactus flight level 180 as a final, Cactus 45. And that means that I just don't have time to work out what the guys want. I'm starting to really be concerned with, like I say, basic separation now.

INTERVIEWER: Any particular area or problem that you're thinking about now?

11:30 Minute Freeze

CONTROLLER: Yeah. I'm realizing that these guys landing at Tulsa are going to be a real problem. At this point, I've sort of, in desperation, accepted the fact that I'm not going to get these guys down the in-trail, and they're going to end up maybe over the VOR at high altitude. I'm going to start to get pretty desperate soon.

INTERVIEWER: Which guys are those?

CONTROLLER: Well, I can see these guys coming in from the northeast. I'm sorry, that's Continental 56 and the Delta. Now at this point, I'll be honest, I don't even know that they're landing at Tulsa. But they're coming to me at 20—descending to 24, heading toward Tulsa. And I'm assuming that they're landing at Tulsa. I haven't looked at the strips, and at this point I don't have time to be looking at strips. That is something that I would expect at this point my help to tell me; to reach over and say, "Delta 12 is landing at Tulsa." I would not have taken any handoffs from Approach right about now. I would have refused any handoffs. I would have stopped that or expected management to stop that.

INTERVIEWER: Again, when we start up the problem, what do you anticipate was the next thing, or what do you recall was the next thing you were doing there?

CONTROLLER: I believe that I was just answering airplanes at this point, just blindly answering airplanes. But I'm still concerned about separation, and that's still my number one priority. I'm still scanning enough, at this point, to think that I've still got them separated. I do specifically remember that, that at least they're separated at this point.

That's the way I feel right now. They're separated, but the sector's going out of control.

INTERVIEWER: Okay. Very good.

11:30 - 14:00 Sequence

CONTROLLER: I'm starting to get a lot of data block overlap here, and that—

As I say, I still see traffic, I think. I still see bad conflicts because I've dumped American 33 at 23, so I haven't lost that yet. I realize I've got a 22, but I realize also that it's going to be a real mess here. It's going to be a real mess in just a short amount of time. But I still feel that I've got separation under control. That's all I've got.

I'm answering aircraft just to answer them.

I'm thinking about the Brash. I remember specifically thinking about the Brash, getting the Brash in, but also thinking that it's just getting so bad that—

I'm taking my lower traffic down, United 89.

United 89 is traffic for the 25 Xray. I remember seeing that. And, once again, I'm still down to just basic separation. I'm not putting the amendments in. United 89, I am putting 11,000 on the guy.

At this point, I just would not be taking any airplanes. I would be trying to recover from what I've got. I wouldn't be taking airplanes from anybody, Approach or the surrounding sectors at this point. I would just stop everything.

I'm obviously behind. Tulsa's flashing him.

14:00 Minute Freeze

CONTROLLER: I do realize that HH is about to conflict with Approach's airspace. I think I holler over there. I might have been a bit late, I'm not quite sure. I don't remember specifically.

I now see that 68412 is climbing to 13. I didn't issue the clearance. I assume somebody's just doing it to get him up and out of the way. But I didn't notice it at the time. So as far as I see now, like I say, it was just pure desperation and I'm just trying to separate airplanes. I'm starting to think now about just getting rid of some of these guys. I remember that. I want to get rid of them, get them out of my sector, just get them on their way.

INTERVIEWER: Were there any particular ones that you thought of, and why did you choose those particular ones?

CONTROLLER: I'm starting to scan the outside of the sector a bit now because, obviously, if they're heading to the west and if they're near the boundary, I can get rid of them sooner. So I believe . . . what I am doing in the next minute or so is I believe I'm starting to flash some of these guys to the sectors around me. I've given up on—the sector is out of control—I've given up on trying to get these guys, the landers, United 89, American 27, American 33—I've given up on trying to get those guys in trail and down to 11,000 to hand them off on Approach. I've got pretty much altitude-separation on them. And if I have to take them over to VOR and put them in holding and stack them off and peel them off the bottom, I'm willing to do that. But I want to get rid of some of these guys, get them off of my scope and out of the way. I remember thinking that at this point. Once again, it's pure basic separation. I still don't really see any separation, any imminent separation problems. But that's all I can say. Everything is kind of going down the drain.

INTERVIEWER: Again, I'm sorry, I think you already told me before, but recall again what you thought you were doing in the next minute.

CONTROLLER: I think that I'm starting to hand off some of these people to the sectors around me. I'm just trying to get rid of them. I'm trying to get some of these guys off of my scope, and just away from them. I want a little relief and I want to try and decrease the volume a bit.

14:00 - 17:00 Sequence

CONTROLLER: At this point, I don't know who is landing where, and I'm not really concerned about it. Like I say, it's just out of control. I couldn't tell you who was landing where, or who the overflights are. I just want to get rid of some airplanes. And I think I probably start flashing a few here in the next minute or so.

It doesn't really do a whole lot. I'm just climbing him up above Approach's airspace. 12,000—I'm not even sure if I saw the Bandit out there.

I may have. I climbed him to 12; I'm not really sure why, to be honest with you. The Bandit is traffic, but I don't remember seeing him specifically.

I remember I couldn't find the guy at 13, United 41.

That's why—but I'm trying to keep my speech rate down, even though it's a facade. I mean, it's just out of control here.

I still haven't taken a handoff on this Southwest 56, and probably wouldn't have. In a real-life situation, I would never have taken that handoff until I was—

Yeah, see, the Air Evac is handed off but—

INTERVIEWER: Go ahead.

CONTROLLER: I still have basic separation. I remember when I climbed the United, I saw the traffic with the Bandit and decided that I had 5 miles and I just went with it. I didn't put it in but I just—ah, I'm updating it now on United 41. I put in the wrong altitude, I believe. I'd have to check that.

At this point, I'm a bit confused as to why these guys are checking on. I haven't taken a handoff, so I assume they just do that automatically here. In a real-life situation, I would not have taken that guy. The surrounding controller would have been required to keep him out of my airspace. I didn't really understand the ground rules there, but I answered the guy anyway. Looking back now, I'm not even sure if this Center—I'm just picking off the Center off the top of my head. But I realize at this point that Brash is not going to get down. I dump him down in a couple minutes here, I believe. I remember doing that—and give him a bad altitude.

INTERVIEWER: Refer to him as—

17:00 Minute Freeze

CONTROLLER: Okay. I think coming up here I give the Brash 3,000, which is legal according to the—I'm looking up at the chart now. I tell him to expedite. My experience with militaries is that he can do it. I give him three, tell him to expedite, and I realize that he's not going to do it. So I still, even as screwed up as it is right now, I still think that I'm seeing basic separation situations. But, like I say, that's all that's getting done at this point.

My concern is just trying to keep airplanes from running together.

INTERVIEWER: Is there anything else that's happened in the sector or that's new in the sector that's affecting that area? Or perhaps the best thing at this point is what are you concentrating most on in scanning the sector?

CONTROLLER: Just basic separation. I'm looking for altitudes now. All I'm doing is looking at altitudes at this point. I'm just looking at the altitude field in the data block and—

INTERVIEWER: Why is the altitude so important?

CONTROLLER: Well, because I don't want to have a systems error and I don't want to run airplanes together. Quite frankly, in a real-life situation, which is what I was told to play this as, I would be concerned about having systems errors at this point.

So that's it, I've accepted the fact that the sector's totally out of control, and all I'm trying to do is keep from having a systems error right now. But I do remember thinking specifically that what I'm probably going to have to do here is clear all these guys that are landing to the VOR, then I'm going to take them out off the bottom of a holding stack. I'm going to clear them all into holding and then clear them out, which is a really terrible thing to do, but I've gotten to that point right now where all I want to do is get the en routes out of the sector. So I want to get the en routes—the guys away from me, you know, out of the sector. The approach guys are pretty much my low priority right now, I'm just not concerned about that. I just want to try to keep them separated and that's it.

But I am flashing guys. You can see. Like I say, I want to get rid of some guys. I flashed Air Evac 742. I flashed the Cactus; I remember doing that. I'm flashing 68412. I just want to get rid of some of these guys, cut down the frequency congestion, and then I'll take care of these approach guys later. Right now my priority is just try and decrease complexity a little bit. And I'm not worried about the arrivals.

INTERVIEWER: Again, projecting out in the next minute or so, do you remember what kinds of actions you're taking, how you're attacking the problem?

CONTROLLER: I'm trying to get the Brash down. I remember that specifically. I now see there was an overtake on Continental 84. I'm not sure that I saw that at the time. In fact, I don't believe that I did. There's a 50-knot overtake there. The Cactus 56 continues to flash. I probably would not have taken that handoff. I see the guys from the east, American 33 and those guys, coming from the east, landing at Tulsa. I'm fully aware of that, but right now my full concentration is trying to keep airplanes from running together. And I just don't care about that stuff anymore.

17:00 - 20:00 Sequence

INTERVIEWER: Okay. We're running again. Just keep talking about what you see.

CONTROLLER: I think I'm probably getting ready to switch a couple of these guys to the surrounding sectors. I'm just falling so far behind here that I'm not even being effective with what I'm doing.

I should have—I'm trying to—I'm not even sure why I gave that guy a 250. I'm sure I was trying to keep him behind American 33, but now it was just a waste of time.

At this point I probably even thought that Delta 711 or Continental 84 were even going to intercept one of the airways and head towards Tulsa. Now, that's an easy separation problem there, with that overtake. And had I seen that, since it's so easy to do, I probably would have just reduced the speed on Continental 84 and matched up those speeds. I could have done that and that would have been easy. That's pretty much my most serious situation now, I feel. Once again, there's no service being provided. But they're basically—they're separated, except for those two.

That's pretty much experience. Like I say, I know Brash is military. In real life he could have done that. I think you'll find that I stop that because I—

—I don't put any altitude on the Brash, which shows my inputs are just gone now. I'm not doing really anything at all. I'm not sure who is landing where.

I'm even calling myself (laughs). And I should have gotten that guy up. I mean, there's no reason not to.

INTERVIEWER: Which one is that?

CONTROLLER: The Delta 48. Yeah, the outbound out of approach. Which, once again, in a real-life situation, I would not have taken.

But I'm still seeing that I've got problems. I still see Hotel-Hotel and Fox Mike coming together there. I believe I saw that. I climbed the guy but I don't put it in the machine. So, like I say, I'm just down to basic separation. About now I'm starting to see that Brash is not going—

—I'm just not interested in any of that stuff right now. I see that Brash is not going to make it.

I had to realize that's my only option, to bring him south of the airport.

And I'm not even—I see now that Southwest was stopped at 10. I should have climbed him, but I'm not really worried about that.

So right now I think what I feel is that . . . I don't have any real ties. I see 224 is here now. Delta 269 and Delta 12—I'm not sure I saw it then but, like I say, the sector's just out of control right now. I'm trying to get rid of guys.

INTERVIEWER: Summarize for me one more time. Just where your concentration is in the sector, what you're trying to do to stay in the problem.

CONTROLLER: Ninety percent of my efforts right now are just going to basic separation. That's it. I don't care about service; I don't care about getting guys down.

Now that I've got two 24's here at—I've just lost control of the sector. I'm not even giving basic separation at this point. I've got 24's coming together all over the place. I've got the 24's here, Delta 12, Delta 269, Continental 56, they're all coming together here. I'm just out of the problem completely. So it's just completely out of control as far as I'm concerned. I'm probably concentrating right now on just trying to get rid of airplanes, getting them away from my sector. I'm concentrating a lot right now on data block separation, too, as I remember, and not being very effective at it. In a real situation I can trackball—move these. Apparently I can't do that here. And I keep trying to do that instinctively. I guess maybe, if I can say anything, it's that I'm trying to revert to basic instincts now and it's not working, and it's really frustrating me because I'm wasting an awful lot of time doing stuff that's not working.

INTERVIEWER: All right. That's real good. I mean, you may not feel good about the situation, but the information you've given me is real good.

(End of Tape B05 interview.)

Work Overload Retrospective Protocol: PERFE, B06-2/14/91

0:00 - 7:25 Sequence

INTERVIEWER: This is retrospective protocol for Bravo 06. We're going to go ahead and start that.

What were you thinking about now?

CONTROLLER: Do I have to key this?

INTERVIEWER: No, just go ahead.

CONTROLLER: At this time I was thinking of trying to set altitude limits and get altimeter settings in. As you can notice, I did not get the altimeter settings in.

INTERVIEWER: Okay. Now it's all frozen, so if you could go ahead and tell me—

CONTROLLER: Part of this was that the keyboard is set up different. I couldn't find the keys. I'm looking for a strip on 68412, and I don't think we had one. I did not know where he was going. I wasn't really concerned at the time, except for the weather. What kind of surprised me later on is that he leveled at 10,000, although he was given a clearance to 13,000 because of the Cactus coming off of Miami. But that resolved itself.

On 425 Xray northbound, I descended him to flight level two, zero, zero.

Not real—okay, I did not give him 13,000, that's why he didn't climb. But I was not aware that an aircraft was coming from east to west here, thus I took him to flight level two, zero, zero. It didn't really hurt me, but it might have worked better had I been aware of what was coming from the east here.

A little surprise was that a problem starts with 2 Foxtrot Mike. Not a big surprise, but—

INTERVIEWER: Okay. What were you thinking about or looking at right now?

CONTROLLER: I was aware that this 68412 leveled at 10,000. But, again, I made the mistake of not giving him 13,000.

INTERVIEWER: Right, yeah. Okay.

CONTROLLER: And the other thing I was looking at was where 6632 Yankee was going. Also, I was concerned about the restricted area to the south, since he was 7, making sure this route did take him north of the restricted area.

Which is 8,000 and below.

INTERVIEWER: Any other plans going on right now?

CONTROLLER: Well, the plans right now are still trying to visualize where Miami and McAlester—these different arrivals are, being an area that I've never worked traffic on before.

INTERVIEWER: Right. Yeah, that's good.

CONTROLLER: And a little concern about the strips, trying to get those things sequenced so that I would have a little bit of a jump on things.

I found that the strips being to the left of the radar scope, having never worked that before, is a totally different visual display, at least for me, than a person would get over here. I don't know if because the call sign now is on the left, or whatever.

INTERVIEWER: Go ahead and just keep talking. Were you working more on the strips now, or the PVD?

CONTROLLER: Well, as soon as this guy called me, I knew that I had a strip sitting over in the proposal bay, so that made it much easier than on the platform. On the platform you would have a blank strip, and you would have to be copying all this information down.

INTERVIEWER: So you were set on that?

CONTROLLER: Yeah. We were totally set up on that. Then I just confirmed that he didn't have a transponder because, again, I'm looking for the lazy way out, the easy way out. When he said no, then I went to the alternate way of identification.

His heading was S, it conformed. More than a 30-degree turn was given.

Then when he wanted the clearance at 12,000, he's in my airspace, and given a 12,000, I cleared him on course. He wasn't into the weather, so I had plenty of time to take him around.

The Cactus 54 coming off—

INTERVIEWER: Is it off of Tulsa?

CONTROLLER: Yeah, he's—no, no. This is a southbounder off of Miami. Cleared at 5. That's SOP on a platform. Why take a guy up to—in this case you could go niner-thousand. It's common practice, at least at our facility, to stop him, tell him when to expect further clearance, take a look at it later and pump him later.

INTERVIEWER: Just keep talking now.

CONTROLLER: Right now, even though I'm giving this clearance to this guy, I'm still trying to figure out where this Air Evac's going to be going. I see Cactus 54 off. I know he's stopped at 5, there's no problem. It should have, but it didn't dawn on me, why this guy's leveled at 10.

I did let 57 Xray know that I just wanted to get him—and maybe I'm within 2-1/2 miles of the boundary—get him back towards the west and then take him around the weather.

I'm again now looking to see where this guy is going.

INTERVIEWER: And there's no strip on him?

CONTROLLER: Yeah. And I did find the ticket. Brash 55 wasn't really a problem. He was just on course, left at 24 for a while. Then the traffic—Cactus, et cetera—later on was dumped at 23 so I could keep him going. And it took me, on Cactus 45, just to get him away from what I perceive as a possible jam up here, since he was headed to Oak City, I cut him a little bit. I decided later to bring him on a heading for on-course. But then the easiest way out was after the point out, was go on a vector to destination. Just pull him out of the picture.

Brash 55, for me to get lower now, I would have needed coordination with Oklahoma City sector. I didn't feel like doing that. Certainly High is still watching him, so it's no problem for him to stay up for awhile. Okay, I finally caught 68412. Climb him to 13. And this helped the problem here. A little confusion on which button to hit on Cactus 45 for the coordination. I had to look for a minute.

INTERVIEWER: How did that help the problem, with the 412?

CONTROLLER: What? Climbing him to 13?

INTERVIEWER: Right. Just to climb—

CONTROLLER: Well, it allowed me—had I done it right away, I could have probably topped Tulsa approach without a point-out to Cactus because of his climb rate. As it turned out, I had to give a point-out because he was held on. This guy that called for the clearance—I don't remember his call sign—I told him to expect departure clearance because I had a point-out and I was a little—this kind of blew my mind up here with 68412 leveling.

Right here, where I see this 31 Bravo Golf—all of a sudden comes on. I wasn't reading the strip, not being familiar. Thus, I took 25 Xray to flight level two-zero-zero when I could have coordinated 31 Bravo Golf down and gotten him underneath the traffic.

7:25 Minute Freeze

INTERVIEWER: Okay. We're frozen here. Now, we may or may not have—let's see, one, thirty-five. Let me just take it back just a tad.

CONTROLLER: Okay.

INTERVIEWER: I think we're okay here. Now, on this, we're frozen at this point. What I'd like you to do is describe what's going to happen over the next minute—so from seven, twenty-five, which is the current time, to eight, twenty-five, just roughly—by doing two things. One, go ahead and review the critical aspects of the aircraft in the sector right now and as it evolves over the next minute. So I'm looking for you to recall, sort of, what's coming up in the next minute. Then, really spend quite a bit of time telling me about what kind of plan that you might be executing and what kinds of strategies you might be thinking about employing to go ahead and take care—I don't know what the workload level is for you here but, you know, go ahead and discuss that as you go through this. Be as detailed as possible, making sure that you mention the decisions that you made while managing within this one-minute timeframe, from seven, twenty-five. So go from here to the next minute. This will stay frozen and you just kind of project out ahead and tell me what's going to be happening here. Give me the key things about the aircraft on it, and then the specific plans and decisions that you'd be thinking about here over the next minute.

CONTROLLER: Okay. Right now, Cactus 45—well, after 68412, I finally realized he leveled at 10,000, instead of climbing to 13. We got him going, Cactus 45. Point-out needed to be made to Tulsa, which added to the workload because I didn't realize 68412 did not have a clearance to 13,000.

Cactus 45 was pulled off to the side with the intent of giving him a heading to join the airway to Oklahoma City. As I said, I changed my mind later on and just gave him a vector all the way to Kansas City. 31 Bravo Golf, again, strip on the left. In the real world, I think a person would have had a clue that 31 Bravo Golf, 25 Xray are wired. To save time coordinating here, and not having found the strip on 31 Bravo Golf, I just descended 425 Xray to flight level two-zero-zero. Like I say, down the line, 31 Bravo Golf, being a McAlester lander, and having to be vectored to the southwest to intercept the final approach course which later on, as it turned out, he didn't want. He wasn't much of a problem. American 27 wasn't really a problem because 1 Bravo Golf was a lander and would start the descent. So there's no factor with a confliction here. 32 Yankee stayed north of the approach area. Brash 55, in 2-1/2 miles, could be started descent. Holding him up eliminated coordination with—I'm assuming this dogleg up here is part of the Oklahoma City sector.

57 Xray needed to go around the weather, that was coming next. The Air Evac said something—nothing about a vector around the weather. And maybe I should have offered that service. But, certainly, he either had visual or else had radar on board, and this could have been low levels. American 27, being a Tulsa lander—as I recall I might have had a little trouble finding that strip.

INTERVIEWER: 33 you did for sure. I know you had some time on that one. I think you—

CONTROLLER: American 27? Yeah, I had a little trouble trying to figure out—I took him direct McAlester, Tulsa 1 arrival. But not being familiar with the area, I was thinking Tulsa was up to the north of here, forgetting he was landing there. But that was straightened out.

INTERVIEWER: Right. Any other plans or decisions that you made in the next minute, so between now and eight, twenty-five?

CONTROLLER: Well, I think that if American 27—if I hadn't been a little confused of where Tulsa was, being a sector I hadn't worked, I would have had the aircraft that requested clearance off the ground. So that confusion on American 27 delayed the guy on the ground. He was still within time parameters upon his clearance, but I could have got him going. And I was aware that he was sitting there.

INTERVIEWER: Any other plans or decisions that you made in the next minute here?

CONTROLLER: None that I recall. I think it was about that time that I was trying to figure out where the Tulsa Approach button was on the overhead here, trying to give a point-out.

7:25 - 9:15 Sequence

INTERVIEWER: Okay, good. Well, we'll start out the problem again. Again, we'll just get you to keep talking and we'll be pausing again here fairly soon.

CONTROLLER: Okay. I have a question before you kick back up.

INTERVIEWER: Sure, go ahead.

CONTROLLER: Just because a voice is going, I can still talk.

INTERVIEWER: Please. Yes, right.

CONTROLLER: Oh, okay. See, I stopped a couple times there.

INTERVIEWER: Right. No, that's fine. You're doing real well. Most people get real wrapped up in listening to the voice, and then they stop talking for good, you know. But it's however you're more comfortable. If you want, you can pull that ear thing out.

CONTROLLER: It doesn't matter to me. I was concerned that the voice—the voice in here does not go on the tape?

INTERVIEWER: No.

CONTROLLER: Okay. That's all I was concerned about. Okay, fine.

INTERVIEWER: You're doing fine. It's working out very well. Okay.

CONTROLLER: I think here's where the confusion came up. I couldn't visualize Tulsa. I was thinking it was—

INTERVIEWER: Okay. Go ahead and—

CONTROLLER: Here's where I am stumbling a little bit.

INTERVIEWER: Go ahead.

CONTROLLER: Then I realized that he was going to Tulsa. I remember struggling, trying to find this strip again, just like I was doing now. Then when it finally dawned on me, he was given the proper routing. Three minutes late, then after total embarrassment—(laughter)—you wouldn't do this on the platform, I hope.

INTERVIEWER: Okay. What else is going on here now?

CONTROLLER: Right here, the 25 Xray was taken to flight level two-zero-zero to get underneath 1 Bravo Golf. At this time, I was not really sure where 1 Bravo Golf was going. He wasn't a concern because American 27 and Delta, being faster, would be in front of him. Thus, I took 25 Xray down. Since Bravo Golf was a lander, he was no problem because he had to be turned southwest and descended for McAlester anyway.

INTERVIEWER: Go ahead and keep talking.

CONTROLLER: And 57 Xray, level 12,000. Again, I was thinking of reaching over and looking for the button to enter the altitude. The button configuration is a little different, I didn't get that done. I got the altitude entered, but not that he was reported level entered. Delta 269, he's started flashing. Again, not on the arrival route; he had to be given that. I should have grabbed him right away and just ran him Tulsa and up.

1 Bravo Golf is now landing. I realize there's a potential confliction. Thus, I went to flight level two-one-zero and he was turned southwest.

9:15 Minute Freeze

INTERVIEWER: Okay. Good. Well, let's take a freeze here at 9:12 and do the same thing. Go ahead and give the situation with the aircraft first—this is, again, over the next minute—and then any decisions, plans, or whatever, that you would be formulating between now and 10, you know, a little after 10 minutes there.

CONTROLLER: Well, the north part of the sector, 57 Xray is level 12,000. There's not a confliction up there. 68412's on top. That's kind of a low-priority area, except for the weather. Air Evac did not request vectors around. Cactus 45 was some concern only in that, not being familiar with the area, I really didn't know how to get him on an airway. Finally, like I said, later on I just to decided to vector him to straight to Tulsa. Brash 55 could come down to flight level two-three-zero. I realized that. I was going to go straight vertical because Brash was landing at McAlester, thus, in no real—it wasn't a priority item to get him down. Very low on the priority list. American 27, Delta 269 at similar speeds. No traffic for them. 2 Foxtrot Mike would be on the west side. 32 Yankee wasn't a factor. Neither was Bravo Golf. That's about all I guess I could say on that.

INTERVIEWER: Okay. Over the next minute, any more plans, decisions coming up?

CONTROLLER: The only decision was, Brash 55 eventually was going to go to flight level two-three-zero. American 27 and Delta 269, just maintain the in-trail and get them into Tulsa. And Bravo Golf was landing. I was planning a straight-in ILS 36 approach for him. So, like I say, that would be a descend in a southwest heading.

INTERVIEWER: Very good. Okay. We'll go ahead. Any other questions before we start it up again?

CONTROLLER: No, if there's something—

INTERVIEWER: Right.

9:15 - 10:30 Sequence

CONTROLLER: You'll lead me on if you need.

INTERVIEWER: Okay.

CONTROLLER: I think about right after this is where I started going under.

INTERVIEWER: Go ahead and indicate about the workload level stuff like that.

CONTROLLER: The workload level wasn't really that complex, except I had trouble relating to the strips because of being on the left side. That was a real—that was a big thing for me. The other thing, the uncertainty of a couple things. American 27, trying to visualize where he was going because I didn't have the strip. I should have used the flight plan readout button, maybe, when I couldn't find the strip on him. Then all of a sudden I realized data block overlap. I remember coming over and trying to and trying to triggle a couple times, then roll the slueball. I probably should have done that only with the numbers, instead of rolling the slueball.

Again, finding the strips and trying to sequence them in a logical order. I did not particularly consider the arrivals a problem until maybe 5 minutes or 10 minutes later.

INTERVIEWER: Why didn't they look like a problem now?

CONTROLLER: They didn't look like a problem because there was plenty of room to turn, descend, speed adjustment. This is not unusual on the platform, to see something like this. At this time Brash 55 was taken to flight level 230, vertical separation with Cactus 45 in order to get him down. The arrivals into Tulsa were not a problem with it.

10:30 Minute Freeze

INTERVIEWER: We'll freeze it here at 10:44. Now, we're getting into sort of the thick of things here. If you can think out again about a minute or so.

CONTROLLER: Okay. My concern when I saw some of these guys coming down was I didn't know what the arrival was into Tulsa.

INTERVIEWER: Right. Now, why don't you go ahead and point out some of the specific aircraft or groupings and discuss them and then discuss any plans or decisions here for the next minute.

CONTROLLER: Plans . . . Bandit 18 at 14,000 wasn't a problem. There wasn't another aircraft at 14,000, unless I was going to put it in there. I didn't really care where he went. Arrivals can be vectored around that type of a thing, unless he started a deviation east around the weather, which he didn't do. Later on, he was vectored for a couple outbounds, but at this time no problem. 57 Xray's level, vertical with 57 Xray. 412 not a problem. Nobody in Air Evac's way. Vertical on Cactus 45 and on Brash. 32 Yankee's on course. 2 Fox Mike's on course.

I've got vertical here, just waiting. A vertical between 25 Xray and 1 Bravo Golf, just waiting for separation—lateral separation to take place so 1 Bravo Golf could continue descent. 1 Bravo Golf's below American 27, Delta 269, which are inbound. I did glance up here, and I wasn't sure where the 6455 code was going. I was suspecting he was an inbound to Tulsa. I was sure these three were. I wasn't too concerned. As we see later on, the 4311 code was put on a 270 heading to run at a different gate. So I wasn't too concerned with him being a problem with the two arrivals on the North.

INTERVIEWER: Any other plans or decisions here in the next minute?

CONTROLLER: No, I think right now it's strictly a case, and I don't mean to sound flippant about this, but you shoot from hip. There's nothing—

INTERVIEWER: Right. Now, how about workload and stuff like that at this point?

CONTROLLER: Workload, normally this would be quite easy. Workload is complicated by two things: I couldn't find the strips, not familiar with the area.

CONTROLLER: Right.

INTERVIEWER: And I remember recalling a couple times, and even looking—I think I looked at the map about this time—trying to figure out what the arrival gates were. So had I been a good student and studied my map—I'm throwing that in for the help of the student.

INTERVIEWER: Right. At this point, you know, you didn't actually ask for help.

CONTROLLER: It was getting there.

INTERVIEWER: You were getting close? But would you require D-side at this point, or not quite yet?

CONTROLLER: I don't know. It probably would have depended on one item. If this weather had been a problem, where guys were starting to deviate around it, absolutely. With the present situation, no. But, as it turned out, after a couple of these guys hit, maybe now would have been—since I was unfamiliar with this, I should have asked for help at this time, maybe not two minutes from now. Just because of being unfamiliar with the area.

10:30 - 11:30 Sequence

INTERVIEWER: Okay. We'll go ahead and start this back up.

CONTROLLER: Right now is where we take gas.

INTERVIEWER: Go ahead.

CONTROLLER: Continental 56, I did glance over and notice he was an inbound. American 33—I was not really concerned about Continental 56 and American 33 because vectors are speed control, would fling them in trail.

I kept looking at this 4311 code, figuring where I going to put him. Later on in the problem it bears out he went on a west heading. Speeds—data block overlap bothered me, and I had a little trouble getting the data blocks apart. But speeds, again, were steady here. Thus, nothing done. Delta, I left run up to the boundary before I turned him to safe coordination with Memphis Center over here on the right. And data block overlap here started getting to me with Southwest 56, Continental 56. Again, speeds were similar. But I did notice that Southwest 56 we didn't have a strip on; similar call signs with Continental 56.

11:30 Minute Freeze

INTERVIEWER: Okay. Now, let's go ahead and project out a minute here, up to twelve, thirty-five. Again, review the aircraft, then we'll go through the decisions and plans you might have had at this point. I think you're getting real close to—I'm getting time projected out where you did ask for help. This is an important period here, so just spend some time talking about it.

CONTROLLER: Well, right now there are a few loose ends, a couple things I didn't see coming.

Well, let's go over the things I did see coming. I knew Delta 269 was a lander. He was not given clearance for the Tulsa 1 arrival. He's still on the jet route. I knew that Bravo Golf in about 5 or so miles would have lateral separation with 25 Xray and would have to be descended. Again, he was not a problem with American 27, Delta 269 inbound. Delta 12 continued to run until he got in my airspace, planning a west heading to go behind these two. In the real world, he might not do this because he probably had a southeast-bound climb corridor. So a person would settle out in a different situation. Again Continental 56 and Southwest 56—it was shortly after this I started getting data block overlap. What I should have done here was thrown 57 Xray data block to the north, Bandit 18's to the north. Again, no headings needed at this time on the Continental 56 and Southwest 56 to get behind American 33, United 89. Plus, they're not in my airspace. I'm lazy. If I don't have to coordinate unnecessarily, why bother the other guy also. Other than that, Cactus 45, about to flight level two-two-zero. Again, a low-priority area because vertical had been established several minutes back. Aware that Brash was landing at McAlester. I don't remember if his request to vectors to final was prior to this time or shortly thereafter. But again, no hurry to get him down.

INTERVIEWER: Okay. Any other plans or decisions coming up?

CONTROLLER: No plans or decisions, except several things: unfamiliar with the area, the keyboard, not getting the data blocks apart. I realize that it's getting to the point where I should get help. Again, maybe there's a slight hesitation here because we know these targets do not have bodies on board. So I think a person may—I would hope that a person would ask for help a little bit sooner in the real world than in the DYSIM lab. After all, a service is about the only thing we can provide, and if a person's under, you can't provide a service.

I think that's about it.

INTERVIEWER: Okay. Good.

CONTROLLER: Oh, one thing. 57 Xray, I was aware that he was coming north to weather. I think about two minutes later he went to a 270 heading on the north side.

INTERVIEWER: Okay. Very good.

11:30 - 14:00 Sequence

CONTROLLER: I think right after this, it turns ugly.

I remember right now looking at the Southwest 56, trying to find his strip, and I think that was the only one I called right that I didn't have a strip.

INTERVIEWER: Yes. Southwest, right.

CONTROLLER: Continental 56, I started to reduce him, kind of because of data block—not overlap, but—I don't know what to call it. Started to slow him and realized I couldn't do that with Southwest. Okay. Laying over there, yes. But Continental 56, I started to slow him because I knew he had to come behind United 89. My plan was to select American 33, United 89, Continental 56, Southwest 56. In that order. United 41 coming off Tulsa. I wasn't too sure where he was going. I had to look over the strip twice to find out where he was going. And he wasn't a problem with anything, as it turned out, with exception of Bandit 14 later on. Bandit was given a little bit of a turn. 377, I saw him coming, took the handoff. He didn't call me until maybe 50 miles, 40 miles down the line. Kind of surprised me at that time. I had to backtrack.

I'm a little late here on Bravo Golf, getting him down. I am about 10 miles here.

Aware of the similar call signs with Southwest and 56—okay. Because I couldn't find the strips, I didn't know he was going to Tulsa. Now, we're starting to bring Southwest 56, so he falls behind Continental 56, who is going to follow United 89. Delta 12. I think it was right after this I was planning a west heading on him. At the time, I wasn't sure if he'd go between American and Delta, but the plan, later on, he definitely would have had to go behind Delta 269. Again, too early to make a decision.

Departures. When Southwest 44 came off, I . . . should have prior to this asked for help. And American 33, United 89, Continental 56, Southwest 56, all had to get underneath the northbound at 22.

14:00 Minute Freeze

INTERVIEWER: Okay. We're frozen here at 14 minutes.

CONTROLLER: Right now it's to the point we're even on the platform. I think a person would definitely want to D-side. We're looking at probably 15 on a frequency, or more, and most of them, in some kind of maneuvering configuration climb or descent. Not too sure where a couple are going.

INTERVIEWER: Okay. Why don't you go ahead and review the aircraft here and then—

CONTROLLER: Okay. The aircraft: Air Evac 87442 westbound, no traffic for him. 68412, no traffic. I remember thinking I had to make a handoff and I did do it a little bit early. 57 Xray, by this time was on a west heading. He was the north side of the weather. Bandit 14 was an overflight; not really concerned about where he was going at the time. United 41, I remember looking down, I think he was out at about 9,000. I figured I could top him, but Southwest 44 later on grabbed me. So Bandit went, I think, if I remember right, to a 250 heading. Brash 44 is not a factor with the departures. Again, landing ILS 36 at McAlester. Plenty of time to get down. 377, there was nothing around that was at flight level 190. I was a little late taking the handoff. 32 Yankee, overflight; no problem with anything. I thought, prior to this that I had Bravo Golf on a heading in descent. I don't know what happened here. 2 Foxtrot Mike, no traffic for him. By this time, I should have had Delta 269 turned to McAlester, the Tulsa 1, which was not done again. A little bit of overtake on speeds with American 27. Delta 12 was going to get pulled out of the picture. There's no sense in S-turning him all over the place. Delta 12 was parallel with American 33 and United 89. Since those two were set up, let them run. Pull the guy out that doesn't fit. Continental 56 was in a turn to a 150 heading, which should have put him behind. Southwest 56, on a 160 at 10 degrees, was out enough to affect separation.

Southwest 44, I didn't know exactly where he was going at the time, but I knew I had a problem with the Bandit on him, being out of 4,000. It's almost impossible to top.

INTERVIEWER: —made your decisions.

CONTROLLER: No, I don't remember what happened to Bravo Golf. I thought by this time he was on a heading in descend, then he changed his mind and wanted to go to McAlester to hold. And he was clear to do that at flight level 210. I guess maybe he was never started down. And I don't know if that was in the problem with American 27 and Delta 269. But, like I say, there was vertical, he was going over the—American 27 was over the top. So this is, basically, a nothing area with the one exception, Delta 269, that should have been turned and wasn't, to join the Tulsa 1.

INTERVIEWER: Anything coming up in the next minute—decisions or—

CONTROLLER: Well, yeah. In the next minute or two the 377 was running up on the boundary. I needed to take a handoff. I had a data block problem here, which bothered me later on. It caused me to get into a jam. The Air Evac, I don't know why we're—not the Air Evac, the Bandit. I knew I was going to have to go someplace with him. And after I found out where Southwest 44 was going, I just pulled him to the north of Southwest 44's track. American 41 and Southwest 44, climbing out. No factor on traffic.

INTERVIEWER: Very good. Okay. Let's go ahead and—

CONTROLLER: The other thing that had to be done. Delta 12, United 89, American 33, all three of those had to be vertically separated from 25 Xray, would have been the easiest way to do it. Or else just dump underneath. Continental 56, Southwest 56, being in a descent configuration, although he was I think cleared to flight level 200. I don't remember what I cleared him to, I'd have to look at the strip. But he wasn't really a problem with 25 Xray. He had to be down for the arrival gate anyway. But, again, getting down to the problem, there's a couple things that could have been done much better. One of them was the Delta 269 turn on. The handoff would have been taken by this time. Southwest 44, the awareness would have been there on that. Looking for strips, it really bothered me—hunting for the strips.

INTERVIEWER: Okay. Let's go ahead and start this back up again.

14:00 - 17:00 Sequence

CONTROLLER: Okay. Here goes Continental 56. Getting him underneath the 25 Xray. American 33, United 89 were not traffic for him. Southwest 56, descending. Not a problem, he's set up also.

Okay. This is about the time I realized 31 Bravo Golf, he was on a heading. I remember that now. Apparently when the student in back asked for holding in McAlester, I cleared him to McAlester and apparently she—no, I did not clear him to McAlester. I think I said I had the request, I don't remember. But, anyway, turned to McAlester; no problem, no possibility of separation loss. When 31 Bravo Golf was on the southwest heading, being vectored to final, that also would have pulled him underneath 32 Yankee. He was overflying McAlester.

I wasn't really aware of where Delta 711 was going. At this time I was looking for a ticket. I found out later on he was overflying. So there's nothing on the north half of the sector that is a traffic problem, with the exception of United 41, Southwest 44, and the Bandit. The main problem was the 2er arrival. American 27 and Delta 269 needed to be watched. Delta 12 was, again, westbound to follow these guys. American 33, United 89, Continental 56, Southwest 56 are set up. Although I remember looking up at the map because I couldn't remember the arrival, and then I gave the wrong one.

Brash is on the descent, nothing really in his way. Bravo Golf's holding, so—since he's holding at the VOR I didn't really consider it a problem. He is going underneath him, but landing, it would be natural he would be below him. Delta 269, I don't remember what I did here, but it looks like he's in a turn for Tulsa, and then in.

INTERVIEWER: Go ahead.

CONTROLLER: Okay. I'm trying to figure out what I was doing now. Okay. Here's where Southwest is coming out. Bandit didn't answer, so my next turn was to a 250 heading. Let the outbound climb out. They were in trail, no problem. I knew at this time that I was under, that I needed help. I really did.

Okay. And I crossed there. I couldn't remember the name of the intersection.

The Delta is being slung in behind the American. Stop the 22 for—

17:00 Minute Freeze

INTERVIEWER: We're frozen here at 17. Go ahead and summarize the aircraft between 17 and 18, anything significant happening there with the aircraft. Then we'll go through decisions and any plans.

CONTROLLER: Well, nothing—the two departures coming out, United 41 and Southwest 44, are a clean shot coming out. The Bandit is established on a 250 heading. Later on he goes back on course.

Brash 55 is in a descent. I don't remember what altitude because I'd have to look at the strips. But being vectored to final, not a problem. Delta 269, I think there was some confusion later on because I couldn't, again, remember the arrival. Delta 12's running at flight level 240. He could have been started down to flight level 210. And he was coming on south gate. At the time, there was a possibility that he would be stuck or vectored in between American 27 and Delta 269. Later on, it was a problem for gusts. Again, this is just too early to make a decision on that, but I was aware of it. He would have been turned. As the problem evolved, Delta 12 would have been vectored behind Delta 269 for the Tulsa 1 arrival. American 33 is descending. I don't remember if I got a speed on him or not. United 89 is well in trail. It was either Continental 56 or Southwest 56, I couldn't remember the arrival. I remember looking at the map, and I gave the Sprins 1 instead of the Forts 1 arrival. Thus, he turned in and caused a separation problem with one of the inbounds that was coming in on the east gate.

Cactus 45 I knew needed to—a handoff had to be made. I think that was done shortly after this because I know he didn't cross the boundary. 68412 needed a frequency change. 57 Xray was about on the north side of the weather. 87742, 2,500 feet there. I don't know what the ATP says on that. Being low altitude, I don't know if traffic would have been issued—would have needed to be issued. I was not planning on doing that.

American 27, by this time, should have been started down. He was high coming in the gate. Delta 269, as soon as he cleared Bravo Golf holding, should have started down. Again, Brash 55 is off to the side of everything. Traffic is not a factor with him. Delta 711, Continental 84, both westbounds. Similar type aircraft. Really, from Tulsa and north, nothing in the sector that had to be watched, except for just to scan.

I think it was about this time that 377 called me and, although I knew he was out there, which was obvious by stopping Brash 55, it kind of—again, I'm hunting for the strip. Where's this guy at? Fox Mike's flying along, there is nothing in his way. I think that's about it.

INTERVIEWER: Okay. Any other plans or decisions here in the next minute?

CONTROLLER: Yeah. I had to make a couple handoffs here. And again, I couldn't remember frequencies or the sector. I think I was mumbling to myself about that. A couple of distractions down the line—

INTERVIEWER: You mentioned, I think in this timeframe, the next minute, something about stopping the strips, even though you still logged a few after that. But I think you made some comment about—

CONTROLLER: Yeah. Since I couldn't find the strips, it was a matter of getting the four inbounds in the east gate down to altitude and over to Approach. I knew I was behind. It was quite obvious American 27 is hung up. Delta 12 could have been started down by now, or should have been started down by now, at least to flight level 210. And the handoff on Continental 84 should have been made. These are things that should have been done so that I didn't get behind in the problem.

And I kind of put strip mark in a low priority, although in the real world that isn't done.

INTERVIEWER: Okay. We'll take it out here to 20 minutes, unless you've got any other—

17:00 - 20:00 Sequence

CONTROLLER: No. No. I had mentioned that these American and Southwest needed handoff to high.

This kind of threw me for a little surprise when Delta 269 said he couldn't join. He was given—oh, I gave him the wrong arrival. I gave him the Sprins.

Again, unfamiliar with the area. But then when I realized that something was wrong, I just put him on a north heading. He's a VME cross and restriction, which I'm sure Approach would have bought.

Delta 12, I don't know where he was at now.

Okay, Delta 12 was started down. Continental 56, something might have told me that I gave him the wrong arrival. I saw the turn and I told him to disregard. I don't know what distracted me at the time, but he should have stayed on the heading to join the Forts 1 and I think I gave him the Sprins 1, and I think that's why he did that. That causes separation problems with United 89 later.

Again, at this time I could have brought Southwest 56 around, but it wasn't going to save him that much. Continental 84 in my airspace, distracted, I should have taken a handoff by now. Memphis Center would have been hollering at me. And Brash 55 could have been started down by now. There's no separation problem with Brash and Delta but, being a service organization, he's what, 40 flying miles from the airport and it's time to get him down.

And again, Delta 12 at this time was put on the Tulsa 1 arrival. At this time he would have needed a turn to the southwest to go behind Delta 269. I don't think I could have fit him in between American 27 and Delta. But worrying about this pulled me away from Continental 56, and this is where that second person helps. And then issuing him the wrong arrival. That's strictly a case of not being familiar with the area. But again, here's old Continental 84 flashing. So I think you can see that when a person gets in a traffic situation, you have a tendency to ignore part of a sector because there's nothing up there. That's going to hurt you. I was going to get hurt on the east side and on the south side here if I wasn't careful. Delta 48 about this time coming off, too, and not really sure about where he was going. I knew climbing to 10,000 wasn't going to hurt me, so I had 13,000. I could sort it out later.

It was about this time that I saw Continental. Maybe 30 seconds later I turned him out and turned the Delta out. And it was going to have to be a dogleg. He got a severe reduction of 210 knots. That was not a problem because Southwest 56 is still on his old heading, which I forgot about. So he could have slowed even to approach speed and Southwest 56 would have not overtaken him. Trying to get something going on separation. The aircraft wouldn't have hit, but there was a separation problem. Bravo Golf continues to hold, I don't know why. Delta's started down. The Brash is going to 8,000. Again well behind 32 Yankee but this didn't hurt him again, and he was behind 2 Fox Mike.

INTERVIEWER: Very good.

CONTROLLER: A handoff was made to the Air Evac. 25 Xray about this time should have been put back on course. I don't know if I ever did that or not. The 68412 needed a frequency change.

INTERVIEWER: In general, as you get into the heavier workload situations, what kind of shift, or whatever, do you do in terms of picking priority things and/or trying to manage your workload any better? Do you—

CONTROLLER: If you get into what now?

INTERVIEWER: Into a heavy workload situation where you've got lots of stuff—

CONTROLLER: Well, there's always two or three aircraft that are key aircraft. And in this problem they were the ones on the east gate and the Delta 269, American 27, and Delta 12. You try to pick those out and, not ignore the others, but they become a low priority unless they scream for help all of a sudden. A person literally can almost ignore a part of a sector at times. Just pick it up on a quick scan to make sure that the pilots are doing what you want them to do.

I think that things on this would have run smoother had I been able to make more of a comparison to the aircraft and the strips. The strips help only if a person is familiar with the area.

INTERVIEWER: Right.

CONTROLLER: I really believe that when a person gets to a heavy traffic situation, you concentrate on anywhere from one to four or five airplanes, and the rest of them take care of themselves. Why worry about something that—

INTERVIEWER: So the key is to pick those—

CONTROLLER: The key aircraft, absolutely.

INTERVIEWER: That's the hardest thing.

CONTROLLER: I don't know if it's the hardest—

INTERVIEWER: What kind of strategy would you use in selecting, or is it something that's obvious?

CONTROLLER: It isn't always obvious. Sometimes just seeing things so many times that you know that it has to be done. That might not make a lot of sense. There are other times that you have to grab one relatively early and literally force the pilots to cooperate, for example, if he isn't cooperating on rate of descent. You may want a good rate of descent so that the speed automatically comes back. Some aircraft are of the type that they can't slow and descend at the same time, so what's running through your head is do I want the speed first, or do I want the altitude first, because I can't get both at the same time. So a decision has to be made there.

I was going to say something, I forgot what it was now.

INTERVIEWER: Now, having sort of reviewed what you did, were there any things—you pointed out a few things that you said, well, I could have done it different. But were there some things there that you probably just did instinctively which really adjusted as the workload or the traffic got heavier?

CONTROLLER: That's what I was going to—let me backtrack a little bit from that. I'll come to that point there. A lot of times in air traffic where you look like you're going to have a potential confliction situation, whether that be two aircraft that are at altitude and you're worrying about lateral or a climb, sometimes if you just hold off, these things just work themselves out. I don't mean to sit back and just kick back and not really take a look at it, but they do resolve themselves. And then what was your other question?

INTERVIEWER: Did you notice when you reviewed it any sorts of adjustments you might have made to the way you handled traffic as the traffic got heavier? In other words, some kinds of adjustments that you might have made to help compensate for the heavier traffic?

CONTROLLER: Okay. One adjustment was Delta 12, pulling him off the gate. I'm behind in the problem at this time. There was no sense in penalizing two aircraft, I think it was the United 89 and American 33, at the time. So the plan there was just to take him to the south gate and get him away from everything.

There were things that I could have done differently. Continental 56 was given the wrong route, and he became a problem with United 89. Southwest 56 could have been turned on sooner. Delta 269 could have been given McAlester Tulsa 1 as soon as he checked on a frequency. I was aware that the Southwest 44, United 41 were not a problem. Again, the Bandit's out of the way also for Delta 48 coming out. So Delta 48 can go on course. I don't know.

INTERVIEWER: Good. Very good. Well, I really appreciate it. Okay. We're done. Excellent.

(End of Tape B06 interview.)

Work Overload Retrospective Protocol: PERFE, B07-2/14/91

0:00 - 7:25 Sequence

INTERVIEWER: This is a problem being run by BO7 on February 14th. The problem is—time now is 2:44.

CONTROLLER: Okay, here I'm still pretty relaxed. I don't have a whole lot of traffic. Just watching the planes fly by.

I scan the scope. I have no traffic, so I go ahead and climb up to 13,000.

Here I'm looking at the limited data blocks coming in to prepare for what's about to enter my sector.

Here I check the routes. Since I'm not familiar with the map I want to make sure I know where this guy's going.

INTERVIEWER: Just keep on talking as the problem—

CONTROLLER: Okay. I'm still watching the two limited data blocks about to enter my airspace, and I see the primary target up south of Springfield. I'm watching him.

I go ahead and move the slueball down and take the handoff on 25 Xray. And then I move the slueball over and take the handoff on 32 Yankee. I look at the strips so I know where they're going.

INTERVIEWER: Are you hearing any of the radio calls?

CONTROLLER: Yeah, very weakly.

INTERVIEWER: Okay. I'm not getting them at all.

CONTROLLER: I answer 25 Xray and I once again check the strip, check his routing.

The same with 32 Yankee. I look at the strip again, trying to keep my strip-marking up right now as long as I can.

I'm basically right now checking over the strips that I have, looking at the aircraft that are coming to me to see what kind of conflictions I'll be having.

There I noticed that 412 had leveled at 10,000 after I had assigned 13,000. So I went back and verified the assigned altitude.

INTERVIEWER: How did you recall that you'd made that call before?

CONTROLLER: On initial contact I remember scanning the scope and there was no traffic, so I'd climbed her to 13,000. I noticed she'd leveled off at 10,000, the original assigned altitude.

INTERVIEWER: Okay.

CONTROLLER: Here I'm trying to concentrate on the aircraft that's calling but the phone's ringing, so I'm distracted so I don't get all the information. I hear a position and I start working on it and then I become distracted.

There I issue a clearance off Miami climbing to 10,000 only, just because I'm not sure where the primary is. We're still VFR, but I pick an altitude I think will be below all my traffic, and then when he gets off, I'll reassess my traffic and give him a further clearance.

Traffic's starting to build up a little now, so I try to move my data blocks around to keep them from overlapping.

I go ahead and issue 57 Xray a vector to establish radar contact with and also what I believe will take clear the weather.

Traffic's started to pick up now. Again, checking all my strips to see where everybody's going.

Once again I answer the phone and then I don't hear Cactus 45 call; I'm distracted. I know somebody's called but I don't know who, so I have to sit and wait for them to call me again.

INTERVIEWER: Okay.

CONTROLLER: I see 57 Xray turn, but I don't get a chance to talk to him again for a few minutes. I just let him fly along VFR until I get a time to issue the IFR clearance.

I check the route on American 27, make sure he's going to Tulsa, and see if I need to issue the arrival to him.

I finally get a chance to go back and talk to 57 Xray, verify the destination and the altitude.

7:25 Minute Freeze

INTERVIEWER: Okay. We're frozen now at 7:25 into the problem. So give me a summary of what's going on in this sector now, just going around or covering all the aircraft.

CONTROLLER: Right now, I have Cactus 45 off Miami climbing to 10,000 only. I need to assign him another altitude. I can go to 12,000 easily now. I have November 68412 that's just en route going northbound. There's really no factor for anybody.

INTERVIEWER: Do you have any actions planned for him?

CONTROLLER: No. I just plan on letting him fly right through and I probably won't even talk to him again until I switch frequencies. Brash 55, I know I need to start him down, but I don't get the chance for a few minutes because I get distracted with the other inbounds I have. I have November 425 Xray northbound at 220, and Jet Commander 31 Bravo Golf inbound at flight level 220. So I know I have a confliction there. 25 Xray is in route, so I don't really want to start him down. I want to start down the first one that's going to be landing. So I need to wait until 1 Bravo Golf enters my airspace before I can start him down.

INTERVIEWER: I see.

CONTROLLER: But I don't want to just sit here and wait for him to enter my airspace, so I go to other things and then come back to him as soon as I can. 32 Yankee just flying along at 7,000; no factor for anybody. The same with 432 Fox Mike. Just flying along, no factor.

I have Air Evac 742 on a vector now to go around the north edge of the weather. And I've radar-identified 57 Xray. I believe I had issued a vector also to clear the weather and I'm trying to get the flight plan information in the machine to see if I already have a flight plan on him.

INTERVIEWER: Okay. The data block that's on 257 Xray now, did you enter that data or did you start track on him?

CONTROLLER: I started the track on him. There's no data entered in there right now.

INTERVIEWER: Okay. All right. Very good. Thinking about the next minute, projecting the situation ahead for the next minute or so, can you recall what your thoughts are or what you were thinking about doing over about the next minute of the problem?

CONTROLLER: I know I was concerned with the 25 Xray and 1 Bravo Golf. And my next move, I believe, was to enter the temporary altitude in on 57 Xray and climb Cactus 45 to 12,000. And then shortly after that I called traffic to Cactus 45 for the traffic at 13,000.

And I believe within the next 60 to 90 seconds there's also another handoff I take following that American 27 also down there.

INTERVIEWER: Any thoughts related to or any planing that you're doing for American 27 or any other—

CONTROLLER: No. I'm not too concerned with him right now. My major concerns are climbing the Cactus and the situation at flight level 220.

INTERVIEWER: Okay. That's with Bravo Golf and 25 Xray?

CONTROLLER: Right.

7:25 - 9:15 Sequence

INTERVIEWER: Very good. Okay. Just keep talking about what's going on in the sector.

CONTROLLER: Here I go ahead and issue 25 Xray clearance to the airport, a vector that will take her clear of the weather and verify the altitude she's at now, and ask her to report level at 12,000.

I'm watching that American 27 and I realize there's traffic coming up behind him. I'm starting to work on traffic a plan for my arrivals into Tulsa.

INTERVIEWER: Which arrivals are they?

CONTROLLER: What's that?

INTERVIEWER: Which arrivals are those?

CONTROLLER: The American 27 and the Delta 259.

I want to climb the Cactus as soon as I can so I'm watching that pretty closely. I should be starting the Brash down but I don't because I'm planning on climbing the Cactus, not realizing the Cactus is only requesting flight level 220. I thought he wanted higher.

I'm looking at the two arrivals to Tulsa on the South—American 27, Delta 269—and I notice there's a 50-knot overtake so I slow the Delta 269 down to 250 knots to—or, correction, I speeded American 27 up to 310 knots to stay out in front of Delta. I want them to get through my airspace as fast as I can rather than slow them down and have them stay in my airspace longer.

9:15 Minute Freeze

INTERVIEWER: Okay. So this is the next freeze-point where we're interested in what's going on. Just summarize the area for me again.

CONTROLLER: Cactus 45 is ready to be climbed now. I initially climb him to 230 and then while I'm saying the altitude and looking at his data block, I realize he only wants 220, so I go back and correct myself. 68412 is still northbound. I have no intention of talking to him until I change frequency. Brash 55 is on frequency. I'm just waiting to start him down. I'll be starting him down in the next minute, minute and a half. Air Evac 742 and 257 Xray I have both on vectors to go north of the weather. I'm watching that, planning on turning the Air Evac back to the west shortly. 1 Bravo Golf has crossed the airspace boundary now. It's getting close to an imminent situation, so I want to get him down. That's probably my first priority right now.

INTERVIEWER: What makes that an imminent situation, or why are you pointing that out?

CONTROLLER: Well, they're both at flight level 220. I've got maybe 25 miles, I've got maybe two and a half minutes to achieve vertical separation before I lose separation there.

Separation's always my first priority, so that's what I'm working on first.

I go back and check the speeds of American, Delta—American 27, Delta 269—to see if they're compatible now. I won't have an overtake situation there.

That's about it. 57 Xray's flying along slowly, so I don't plan on doing anything with her for the next 4 or 5 minutes.

INTERVIEWER: Again, projecting out for the next minute or so, what do you anticipate happening in the sector over the next minute?

CONTROLLER: Within the next minute I'll be climbing the Cactus 45, starting Brash 55 down to flight level 230, and I'll also start Delta 269 down to flight level 230 shortly after it enters my airspace. I create a confliction between Delta 269 and Brash 55 mainly because I have them both at flight level 230. And I make the decision that I'll descend the Delta below Brash because Brash is a high-performance aircraft and he can descend better. If I hold him—if I keep him up to high, he has to dive into the airport.

INTERVIEWER: Okay. Very good. Anything else?

CONTROLLER: The only thing else I'll be monitoring is 425 Xray and 1 Bravo Golf to ensure 1 Bravo Golf gets below flight level 210.

9:15 - 10:30 Sequence

CONTROLLER: Okay. There I climb the Cactus 45 to 230, realize that was an error, go back and correct it to flight level 220.

I tell Brash 55 roger on his request for the ILS. I'm not sure if I'll be able to give it to him or not.

1 Bravo Golf requests holding. I'm getting too busy to have a plane just making circles in my airspace so I tell him unable. I don't have time to have him flying around out there.

I see 1 Bravo Golf is below 25 Xray so I'm not too concerned about that anymore. I start formulating the clearance I want to give 1 Bravo Golf for the clearance into McAlester.

I see I've got two tied going into Tulsa so I start thinking about that. I'm not too concerned yet.

INTERVIEWER: Which two are those?

10:30 - 11:30 Sequence

CONTROLLER: Continental 56 and American 33. Now I go and I check the routing on Bandit 8 because I have Continental above him and Continental needs to get below him. So I check the routing there.

I should be starting Delta 269 down to flight level 230 here shortly, putting him in confliction with the Brash 55.

I realize I've let Air Evac 742 go too long now. I turn him back to the west because he's clear of the weather.

11:30 Minute Freeze

I realize I'm going to have a major sequencing problem going into Tulsa on the east side with Delta 12, United 33, United—I can't read the call sign—Continental 56, and Southwest 56.

INTERVIEWER: Okay. I'm sorry, go ahead. I didn't mean to—

CONTROLLER: Okay. When I see I have basically five arrivals into Tulsa coming in from the eastern boundary in about a 15-mile stretch, I realize I'm going to have to issue some vectors and some speeds. So now most of my intention is focused on who I'm going to make one, two, three, four, and five, and how I'm going to carry it out.

I pick United 33 to go first. I give him a shortcut and then I basically—I let Delta 12 stay at normal speed. I think he'll fall right in behind the United if I just let him run. And I just slow the other three down and I'll make a decision on where those three are going to go. So I've picked number one and number two, and I'm not sure about three, four, and five yet.

INTERVIEWER: Okay. What else is going on in the sector at this time?

CONTROLLER: Air Evac 742 probably should be my next biggest concern. Too close to the center boundary; I should be turning him. He's gotten away from me. 57 Xray is getting ready—I'm about to turn her back to the west to clear the weather.

I'm watching Cactus 45 still climbing to 220, debating whether to start the Brash 55 down. I decide against it. I'll wait. And I look down, American 27 and Delta 269, the speeds still aren't working. I have a slight overtake. So I slow the Delta 269 down under 280 knots. 1 Bravo Golf is cleared for approach, not really a factor anymore. I just need him out of 6,000 before I can terminate him and send him over to the tower. 25 Xray is obviously becoming a problem for all my Tulsa arrivals coming in from the east, so I'm trying to work out an altitude strategy, what altitudes I'll be using.

And 2 Fox Mike is still no factor. And 32 Yankee is really no factor right now.

INTERVIEWER: Okay. Going back up to the 257 Xray and 7742, how do you know that it's time to start moving them back now, or why is that moving up in your priorities now?

CONTROLLER: Well, the Air Evac 742 is too close to the center boundary. I should make a point-out there. If I had time or help, I'd probably be making a point-out to the Kansas City sector. And he's clear of the weather so he should be turned. I want to get these guys through my airspace as fast as possible.

57 Xray can go a little further, but I can go ahead and start the turn now. I believe I turn to a 270 heading to just take her around the northern tip of the weather. Bandit 18 I'm not concerned about. There's no traffic for Bandit 18.

INTERVIEWER: Again, projecting ahead for the next minute or so, what do you see as the actions you took or what do you recall as the actions you took in the next minute after this?

CONTROLLER: Within the next minute and a half, I assign some lower altitudes to the arrivals on the eastern boundary. I'm not sure which one got one right now. I know that was a concern, I needed to start getting them down. I also want to get the traffic out of the high-altitude sector and into my sector. So that's going to be a top concern, getting those guys into my sector.

INTERVIEWER: Which ones are those that are transitioning from the high altitudes?

CONTROLLER: The ones that are above flight—flight level 240 and above: Delta 12, United 33, Continental 56, and Southwest 56. I believe since I gave United 33 the shortcut, I think I start him down to flight level 200 first, just to get him started down into my airspace. And then, as he gets a little closer to the airport, I'll just descend him to 11,000 and issue the altimeter.

INTERVIEWER: Okay. As I recall it here, it's really the arrivals on the eastern side of the sector that you're sequencing.

CONTROLLER: That's my biggest concern right now. I still have the Delta 269 and Brash 55 head on at the same altitude. But I have 5 minutes before I need to be concerned about that.

INTERVIEWER: Very good. Whenever you're ready.

11:30 - 14:00 Sequence

CONTROLLER: Okay. I take the handoffs on the arrivals coming in on the east side: Delta 12, United 89, and Southwest 56. I'm still debating who's going to be number three, four, and five, and trying to figure out how I'm going to separate from the 25 Xray at flight level 220 cutting through the arrival corridor.

I look back at the speeds of American 27, Delta 269. I want to get that Delta started down but I can't until the speeds are working or I can use altitude, so I have to start the American 27 down so I can use altitude separation.

United 41 is flashing a handoff off Tulsa right now. I don't need another person on frequency so I just don't take the handoff until I have a little more time that I can talk to him. The same with 377. I'm too busy with what I have right now so I don't want to let anybody else in until I have time to work him.

I realize that 1 Bravo Golf's not going to be a factor for 32 Yankee, so I prepare to go ahead and terminate radar with him and ship him to the tower frequency.

I finally get Air Evac 742 turned back to the Southwest. And I'm preparing to turn 257 Xray back to the west. I'm trying to make the handoff to Kansas City with 68412, but not having much success.

I've got American 33 on a 270 heading now, descending to 11,000 to stay out in front of Delta 12. Right now I pretty much decide that I'm going to make—that it's going to be American 33 that will be number one, Delta 12, United 89, Continental 56, followed by Southwest 56. That'll be the order.

14:00 Minute Freeze

Tulsa calls on United 41. They want me to take the handoff. I look. With him going out on the bold departure, he's no factor. I take the handoff. Okay.

I go down and I look at the Delta 269 and the Brash 55 conflict again, and I start Delta 269 down to flight level 180, I believe.

I'm working on my altitudes—

INTERVIEWER: We're frozen at 14 minutes. Go ahead.

CONTROLLER: Okay. I'm still concerned about the altitudes between Delta 12, United 89, and Southwest 56 with the 425 Xray that's coming northbound. So I'm debating what altitudes I'm going to use. I've decided that American 33 is going to stay out in front of Delta 12 with no more work on my part, so I go ahead and—I'm preparing to descend Delta to 11,000 and then I'll be finished speaking to him except for the frequency change. There's nothing left to do with Cactus 45 except change the frequency. 377, I just let him keep flashing. 32 Fox Mike I'm just watching, there's no factor. 32 Yankee just flying through at 7,000. 1 Bravo Golf, I'm ready to go ahead and terminate him and get him on the tower frequency before I forget about him.

I realize the speeds aren't working still between American 27 and Delta 269 so I slow the Delta down to 250 knots.

INTERVIEWER: A couple of minutes ago you said you would stop accepting some of the handoffs there. How did you know that that was the time to stop accepting? What changed in the situation?

CONTROLLER: When I don't have time to—when I lose track of the planes that I'm already talking to, I'm making turns for vectors late, or I'm not making the handoffs that I need to make, I can't keep up with my strip marking, then I've decided I have enough planes and I don't need to talk to any more. I'll wait until I get rid of three or four of them, or at least till I feel more comfortable with what I have, and then I'll usually start accepting ones that aren't in confliction with anything I already have. And once I take care of those—

INTERVIEWER: Any particular signs that are the signs of discomfort when you're getting to this stage of busyness?

CONTROLLER: Just an uneasy feeling that I might be missing something that I'm looking at. I'm constantly scanning the scope to see if I'm missing something—something—it's hard to say. The overtake situations, two guys coming together at the same altitude, something like that. It's just an uneasy feeling, become distrustful of the decisions that you made. You want to go back and check everything again, and check it again and again.

INTERVIEWER: Yes. Okay.

CONTROLLER: Like I said, there's not much else going on. I'm ready to take the handoff on United 41. I can climb him right to flight level 230 with no factor. I'm still working on the sequencing problem on the east side of the airspace with the five arrivals into Tulsa and the 25 Xray going northbound through that group of traffic. And that's about all I'm working on right now.

INTERVIEWER: Okay. So projecting out into the next minute, what are you going to be doing about those situations, or what are you planning for?

CONTROLLER: Now I'm becoming more concerned with the Delta 269 and Brash 55, and that'll probably be one of my first priorities, will be to start the Delta down and I also want to get the Brash started down because he wants the approach but I am not going to be able to give it to him right now because 1 Bravo Golf is on it. I'm formulating what I want to do until I can give him his approach. Right now there's not a whole lot I can do with the arrivals on the north side—or on the east side, the five arrivals. I'm just watching it, basically still debating what I want to do there. I decide to turn the Delta about 10 or 15 degrees to the left, and he's slowed down to fall behind United 89. And I turn Southwest 56 about 25 degrees to the left to keep him behind the Continental and also to build in some extra room.

14:00 - 17:00 Sequence

INTERVIEWER: Just a second.

Okay. We'll go ahead and see what happens.

CONTROLLER: Okay. I believe I'm starting Delta 269 down now. That would probably be one of my first priorities. And I'm still trying to work on the handoff with 68412. He's coming up on the center boundary and I can't get the handoff completed.

I'm reassessing the situation with 25 Xray and Delta 12 and United 89. Delta 12 needs to get below 25 Xray and United 89 also is at the same altitude. United 41's checked on. Looking at his route of flight, I decide to climb him to 13,000 for now to make sure he clears the Bandit, but shortly I'll go ahead and climb him and realize it's not going to be a factor.

I've started Delta 269 down now, and I'll be issuing him a speed shortly to ensure he stays behind American 27. I'll start the Brash 55 down and issue holding instructions to him shortly. I want to get aircraft off my frequency, so I shift Cactus 45 to the next sector. 68412 I consider the handoff completed now and I ship him to the Kansas City Center.

I want to start—I want to get rid of some of the airplanes I have now, I have too many. So I start looking to see which ones I can get rid of. American 33, I make the handoff on him.

American 27, I need to go ahead and descend him, get the handoff made. The phone's ringing but I don't have time to answer it, so I just let it ring. They'll eventually hang up.

I've turned the Continental 56 and Southwest 56 both out now to follow the other three arrivals on the east side. I get Delta 12 started down to 11,000; I know he's going to stay behind American 33 by looking at the speeds. The speed I have on United 89 looks good to follow the Delta 12, so I just send him to 11,000, keep him going.

Okay. I go ahead and climb the United 41; I realize he's not going to be a factor with the Bandit 8. Southwest 44 is about to check on frequency, and I'm going to go ahead and climb him also.

I've got Delta 711 and Continental 84 both on at the same altitude. I realize there's an overtake situation, so I'm going to start monitoring that. My first intention would be to try to speed Delta up.

17:00 Minute Freeze

I need to start American 27 down so he can cross Wagon at 11,000, and I need to start Delta 269 down also.

I realize 377 made a 360 because I wouldn't take the handoff, so I watch that for a couple more minutes, and then I'll go ahead and take the handoff.

I get United 89 started down to 11,000. I go ahead and switch American 33 to Tulsa frequency and ship Delta 12 to Tulsa frequency, get a couple of aircraft off my frequency.

INTERVIEWER: We're frozen at 17 minutes at this time. So summarize the sector for me again, just what the situations are.

CONTROLLER: Okay. Right now I'm a little late starting American 27 down to 11,000. I need to get him started down and the handoff made. I've got Delta 269 slowed down behind him; that's no longer a problem. I have Brash 55 at 230. I plan on putting him in holding, so just leaving him at that altitude's not really any problem. 1 Bravo Golf is talking to the tower; no problem. 32 Yankee is no factor for anybody. 2 Fox Mike, no factor. Cactus 45 is gone. I've got all the arrivals started down except Southwest 56 on the east side and I've got a pretty good lineup going now. Nobody's a factor with the 25 Xray anymore except for Southwest 756, and the heading I have him on I'll keep him clear of 25 Xray until I can start him down.

I'm getting ready to turn Continental 56 back to follow the United, and then shortly behind that I'll get that Southwest 756 turned back also.

United 41, I'm ready to flash at the high-altitude sector and get him off my frequency as soon as I can. And Southwest 44 never checked on frequency, so I called him and went ahead and climbed him just because I want to get him going also.

I'm just watching the Bandit 8 fly by. Like I said, I'm watching the overtake situation between Delta 711 and Continental 84. I've got Air Evac 742 on a heading that'll take him—I'm about to issue him direct Ponca City, I believe, and then Victor 2, something like that. And 57 Xray, I still have that aircraft on vectors to the airport. I'm wondering if she's at 12,000 yet. She never acknowledged reaching 12,000. That's it.

INTERVIEWER: Okay. So, again, project forward and tell me what's going to happen in the next minute on the—

CONTROLLER: In the next minute, I'm going to go ahead and take the handoff on 377 because at that altitude he's not a factor for anybody. Now, one of my next priorities will be getting the American 27 and Delta 269 both down to the required altitude. The handoff's completed so I can get him off my frequency. And United 41, I want to get the handoff completed. Southwest 44, I want to get him climbed and the handoff completed. That's about it. Like I said, I'm just about to turn Continental 56 back to the southwest to stay behind United. I don't want to put too many miles in between them.

INTERVIEWER: How are you generally deciding on those priorities in the sector right now?

CONTROLLER: What action has to be taken first, American 27 has to cross Wagon at 11,000, and I've only got about two and a half, maybe three minutes before he's at Wagon. So that needs to be one of my biggest concerns right here, getting those two aircraft down now that I've got the in-trail established. Delta 711 and Continental 84, I have a separation problem there but I have some room in there, so I have a few minutes to play with where I can still do something. I can achieve vertical separation or get some speeds working, and I think I decide to use vertical separation.

17:00 - 20:00 Sequence

INTERVIEWER: That's good. Let's go ahead.

I'm holding the tape to try and get us back in sync a little bit.

Okay, you can go ahead and keep talking about what's going on.

CONTROLLER: Okay. I get the American 27 started down and I make the handoff to Tulsa.

I get Continental 56 turned back to the Southwest and I'm preparing to descend him.

I'm looking at Delta 711 on—I think I look at the strips and decide he's the one I want to take down, so I descend him to flight level 180.

I've got Air Evac 742 clear of Kansas City Center's airspace, so I'm planning him direct Ponca City and getting the handoff completed on him, get him off my frequency. 377's already made a 360. I'm going to go ahead and take him because I don't have any traffic for him. I get Delta 269 started down to 11,000 and the handoff made. Now I can shift both those aircraft over to Tulsa Approach.

I'm sure I'm turning—I'm just about to turn Continental in now and continue his descent to 11,000, and I'll turn Southwest right after that. United 41 is ready to go a high-altitude frequency. I'm watching Southwest 44; I have the frequency change made so as soon as he's at flight level 180 I'll change frequency. 57 Xray, I'm just watching her fly. 32 Yankee's still no factor; I'm scanning my scope to make sure I'm not missing any separation-type problems. Delta 48 I see on the scope now. I'll be taking the handoff on him shortly; there's no traffic for him, there's no reason for me not to.

I've got Continental 56 turned in now, and I need to make the handoff. And I'll be turning in Southwest in and sending him to 11,000 and also make the handoff.

377 I think checks on about now, and I check his routing to see where he goes.

I finally start Delta 711 down, deciding on vertical separation instead of using speed control up there. It's just a little easier for me to change the altitudes than issue speeds; I have to monitor it more closely when I use a speed control.

My job's gotten a lot easier now. I'm just about done with the arrivals into Tulsa from the East side. There's not much left for me to do there, maybe one more turn and a frequency changes, so I'm not as busy as I was 3 minutes ago.

INTERVIEWER: Okay, very good. Let's go ahead and freeze here. Let's go around one more time here. Let me ask you about one other thing before we—if I can remember what it was.

A couple of minutes ago you said you were scanning around the display, looking to see if there were any other conflicts. Why had you decided to do that at that particular time, or why did that seem—

CONTROLLER: Just that I thought I had everything—in my mind, I had everything completed and I'm looking for something to do now. I'm actively searching out something to do. Whenever I have 10 or 15 seconds free where I'm not talking, then I can . . . stop tunneling in on one thing and I've got to look at everything to make sure I'm not missing anything.

INTERVIEWER: Okay, good. Thank you. Just scanning around the display now, you kind of summarized the situation before, but anything else about what you're thinking or planning for now?

CONTROLLER: No, not a whole lot. I'm starting to relax a little more now. There are a couple of handoffs to be made, nothing urgent; some frequency changes that need to be made. All my separation problems are taken care of.

INTERVIEWER: Okay. Which separation problems particularly made you feel that you were over the hump and the problem might be getting a little easier now?

CONTROLLER: The Delta 711 and Continental 84 once I decided to use vertical separation there. And I've completed the sequencing for my arrivals into Tulsa on the east side. There's nothing left for me to do there but make a couple of frequency changes. I know I might have a confliction with the Delta that's just airborne off Tulsa and the 25 Xray, but I'm not talking to the Delta yet, so I'm not too concerned about it yet. I'm not even sure which way the Delta goes yet.

INTERVIEWER: Okay. How did you feel at this point about your marking of the flight strips and your other maintenance tasks, maintaining the data blocks and like that? Do you feel you kept up with them or—

CONTROLLER: I keep up with the data blocks just because I have to see who I'm talking to. I can't call a plane if I can't see his data block and what the call sign is. So I also always want to know what altitude he's at. Strips are the first thing to go. If I'm issuing vectors, I can usually tell from looking at the direction the aircraft is heading approximately what vector he was on and I know where I want to take him. So that really doesn't come into play. By this time I should have a good idea of where everybody's going, at least the approximate route of flight, if they're landing in my airspace or not.

And that's about it.

INTERVIEWER: Okay. Real good. That is, I think, really all I need—well, go ahead and project for me again. We ran the problem up to about 21 minutes. Project for me now where you think the problem's going next or what you'd be planning for at this time.

Or just recall what you did as we went along.

CONTROLLER: Okay. The next thing I'm thinking about doing is getting some more planes off my frequency, catching up with things I got behind on. I need to make the handoff on Air Evac 87742, on 2 Foxtrot Mike. I need to start formulating something for the Brash 55. I'm ready to shift Delta 269 to Tulsa's frequency.

I really don't have anything else to do; I'm just getting caught up. There's a lot of airplanes there but there's absolutely nothing for me to do. They're just on my scope, but there's nothing for me to do.

INTERVIEWER: How do you know that they're pretty well separated and that there aren't any real conflicts there? Is there anything that you're looking for as you're scanning around that tells you that everything is pretty well taken care of?

CONTROLLER: Well, certain things I keyed on, like altitudes. I'll look at—like the 425 Xray. I realize he's coming across at flight level 220. Anytime I have somebody at flight level 220, or will be descending through 220, or climbing through 220, I'm going to try to key on looking for him and if it's going to be a factor. Where will they cross at, judging by the different speeds, routes of flight, if it's going to be a factor. Right now basically I have everybody altitude-separated, and the ones that I don't, I've already assigned speeds and they're all working. So I really don't have a problem there.

INTERVIEWER: Very good. Okay.

CONTROLLER: That's it?

INTERVIEWER: I think that's it. Well, again, let's go around one more—can you remember what you were looking for the next thing as we started up here or what do you recall as your next sequence of actions or your thinking?

CONTROLLER: Like I said, things I'm pretty sure I start doing now is making the handoffs on 2 Fox Mike and Air Evac 742. I think I turned 57 Xray to about a 230 heading.

I'm going to take the handoff on the Delta out of Tulsa. Look around for data blocks that I have on my scope that I can take off, like the 6841 whatever it is going up into Kansas City's airspace, Delta 12 going into Tulsa's airspace. Try to clean up the scope so I have a better picture of what I'm actually working right now.

INTERVIEWER: Okay. Very good. Thank you. Excellent run.

(End of Tape B07 interview.)

Work Overload Retrospective Protocol: PERFE, B08-2/14/91

0:00 - 7:25 Sequence

INTERVIEWER: Okay. This is retrospective protocol for participant B08. Thomas, we are ready to start rolling here? Go ahead and look up at the screen.

CONTROLLER: What a job. Okay.

INTERVIEWER: That should be synced up there. Go ahead and just start.

CONTROLLER: Yeah. One of the things that—working from Salt Lake is that we have high terrain everywhere. So the first thing I always do is look at the altitudes, because it's amazing for me to look at an altitude and see it that low.

INTERVIEWER: Since we're rerecording—

CONTROLLER: Oh, the whole thing, again?

INTERVIEWER: Yes. Sorry about that.

CONTROLLER: All right. What I'm doing is looking for matching the routes against the altitudes. Like I said, in Salt Lake we have high terrain, so to see a guy at 12,000 feet would probably automatically be a no-go, particularly like this guy comes up at 7,000. You say, well, he'd be a submarine at Salt Lake. So we look against the high terrain, check him that the file routing, interceptor, if they're on the route and within the confines of the routes.

INTERVIEWER: Were there any specific problems here? Everything looked fine.

CONTROLLER: No, everything was copacetic here. I was looking at the weather, and deciding whether when I got all of my arrivals that I could see when we're coming to the latter part of the problem, whether I'd be shutting off my approach gate or not . . . because in a real world situation that kind of weather would probably pretty much eliminate your arrivals coming in that way. In fact, they probably wouldn't come anywhere near this, and they'd be down here somewhere.

INTERVIEWER: Anything else going on right now, or looking at it again—

CONTROLLER: No. Three airplanes, no big problem.

Like I said, when I've got this guy at 7,000 feet, that's unheard of where I am, so I look and correlate it to the data that's on the strips. I look at the map to make sure that's where it was. I remember earlier saying 12,200 feet was the MAA.

And, in fact, when we've got that Aztec up there later in the problem because he was at 12,000. And for some reason I was thinking that 12,200 was the minimum, so I didn't want to vector the guy.

INTERVIEWER: Okay, looks like we've frozen—no, no, we're moving.

CONTROLLER: That's about where we stopped the last time, where we seem to be going.

INTERVIEWER: Okay. Anything else here, now?

CONTROLLER: No.

INTERVIEWER: So at this time, really, even based on what you know of the strip stuff, you're not doing any kind of forward planning or any great—

CONTROLLER: No. Once I determine—be looking at the file routing, where they are in relation to their routes, and monitoring. That is what you'd be doing. That's moving away too because I expected to sort of be tracking this guy and I couldn't do that. And then it finally dawned on me the guy's an Xray and he doesn't have a transponder.

INTERVIEWER: Okay. What are you thinking about now?

CONTROLLER: See, this is where I started the track, and I was trying to get a code, and I couldn't figure out why I couldn't get a code. It's a matter of being unfamiliar with this equipment and the inputs. What was that? Oh, that was the line, yeah.

INTERVIEWER: Right. Okay. So now what are you thinking about?

CONTROLLER: I'm going crazy trying to figure out how to start a track and get a code on this guy, and I know—I hear this thing finally ring and it dawns on me who he is.

As a result, my attention is away from the rest of the stuff going on. You should be able to do the input simultaneously while you're talking and thinking.

INTERVIEWER: Okay. What are you thinking about now, or what's going on?

CONTROLLER: I'm still thinking about this problem, even though I clear this guy out. See, I would have stopped him if I'd paid much attention to it. That and the fact that the guy was ready to go right now. That far away he'd probably be over the top of this guy, but in this environment I think I'd better move slow.

INTERVIEWER: Yeah. Okay. How about now?

CONTROLLER: That's back to this—my attention in this problem is trying to get a track going with this guy.

INTERVIEWER: Right. So now you're still working on that problem?

CONTROLLER: Yeah. I wonder why I can't get a code on him. That's about the time I figure out oh, hell, he's primary, so—we just don't do that that much.

INTERVIEWER: Now, have you moved on to other things now?

CONTROLLER: Yeah. It's dawned on me that this guy—I want to talk to this guy because I need to protect him from this guy, and I'm looking—

INTERVIEWER: Okay, so what are you—yeah.

CONTROLLER: And then I'm looking at the system, and I'm sure he's a lander somewhere so I go back and show him where he's going to land at and how that's going to fit into my pattern and who I need to get him underneath and so forth.

INTERVIEWER: And what are you figuring on doing there?

CONTROLLER: And then I'm thinking back to this guy who had requested radar vectors. I'm stuck in this 12,200 thing, so I never gave him the service he asked for.

INTERVIEWER: Okay. How about now?

CONTROLLER: And the phone rings and my attention goes to that.

INTERVIEWER: Okay. What are you thinking about now or planning or working on?

CONTROLLER: I'm formulating that clearance. I don't remember what I said to this guy.

Yeah, I got that, so I determined the altitude and so forth. Now, I'm looking at this guy and see if he's landing and then whether I—the clearance I need to formulate to get him on the Tulsa 1 arrival.

INTERVIEWER: What's going through your mind right now?

CONTROLLER: I'm still thinking about this, I think.

INTERVIEWER: Really? That's still taking your attention, huh?

CONTROLLER: Yeah. That and that I knew—about this point too, that this guy was traffic for him and I wanted to talk to him. Yeah, I got the altitude here.

7:25 Minute Freeze

INTERVIEWER: Okay. We're frozen here at 7 minutes, 28 seconds, so what I'd like you to do is spend a minute, sum up the whole situation here by basically giving me any important factors of the various aircraft. Probably as much as possible on the most important on down and just sort of cover the whole sector. Then, once you've done that, then go back through and sort of project out for a minute here and tell me some of the significant things that are going to be happening between now—7:28—and 8:28, roughly. You know, what's upcoming, some of your upcoming plans, some of your upcoming actions, and some of the decisions that you made in that next minute.

CONTROLLER: All right. This guy I pretty much disregarded since he was in the altitude and he was okay. Brash 55, I knew he was landing at McAlester, but I had to get him down reference these two departures that were going out this way. Of course, I didn't have time to look initially to see where these guys were going other than clear this guy. So Brash 55 I know is a McAlester lander. These two guys I know I need to get clear of this guy and then up and climbing, but I wasn't sure exactly where they were going.

INTERVIEWER: You didn't have a plan at this point or a specific—you just knew you—

CONTROLLER: No, just (inaudible) departed and then worry about it. This one was still in the back of my mind because I knew I was screwing this up, the fact that I finally got him identified and knew who he was. And then I would—it's against my nature to take him to 12,000 feet and vector him somewhere, so I didn't want to do that. This one initially heading—I put him at an initial heading I thought would clear. Later I realized that that wouldn't do him any good, but at that time I was too far behind to worry about it. So we're down to here. This guy is en route and this one's a McAlester lander, we determined that. I need to get him down underneath him.

INTERVIEWER: Okay. When you say him—

CONTROLLER: These two going up.

INTERVIEWER: Okay, right. Right.

CONTROLLER: These two were traffic here, and so I should get him down so he's not a problem with this one.

INTERVIEWER: When you mention them, it's good if you can go ahead and indicate the calls or just even the last part of them, American 27 or whatever, because this is all going to be sort of looked at in the abstract here. But go ahead.

CONTROLLER: So Bravo-Golf was to land at McAlester, I needed to get him down and clear the approach airspace. And then these two guys I have to get out of his way or he's out on a vector to ILS to get underneath them. Okay.

This guy's en route so he's not too much of a problem.

INTERVIEWER: Who? American 27 or—

CONTROLLER: 25 Xray. American 27 is the Tulsa one that I needed to get on the Tulsa 1 arrival. So I have to formulate the clearance for American 27. I knew I needed to do that. So other than that, it wasn't too bad.

INTERVIEWER: Okay. Now, projecting out a minute from here—

CONTROLLER: I'm trying to remember what else we had in the problem. Oh, he wants to go into holding.

INTERVIEWER: Who's this now? Bravo-Golf?

CONTROLLER: 1 Bravo Golf requests his holding here. And that would interfere with Brash 55 who also has to land at McAlester.

INTERVIEWER: Okay. Anything else that you've planned or any decisions that you made sort of in the next minute or so that you remember?

CONTROLLER: No, I was just trying to formulate—you know, normally for an arrival gate like American 27 you'd give them cross a point at an altitude that interfaces and speed and so forth. In this case, the Tulsa 1, I go back and think we have to descend them to 11,000 and anticipate that they'll go down in that way.

And when you go to use the speed restriction, sometimes it's not to your advantage to—mostly—well, let me reword that. If I was working traffic in this situation, I would get him across this point at altitude at a speed. But that doesn't work here and it's dicey on him. So I'm going to have to get him down and then give him the speed restrictions. Whereas in the real world you might want to finesse that a little bit and say, well, I'm not going to not say anything about the speed restriction until I go to pop him off to Tulsa, like I did with the first arrival here, because I didn't say anything about his speed until I went to ship him over because I wanted him to speed up. And you do that in the real world. These, they don't finesse too well, but it's still hard to get out of the habit. Other than that, there wasn't a lot that I was thinking about. In fact, I didn't even see this situation, I don't think, immediately. I just picked it up on my scan. I looked around and I said oh, shit. So I'll get him down.

7:25 - 9:15 Sequence

INTERVIEWER: Good. Well, let's go ahead and we'll start it up for just a little bit more and then freeze it again. Once I start it up, just go ahead and keep talking through about other upcoming stuff, even though you've already mentioned some of it. Okay?

Okay, go ahead.

CONTROLLER: One thing to do is I knew at this point I was a little unsure of the area and so forth and I was getting a little nervous. But I knew it was important not to get stuck on some place and get tunnel vision, just to keep increasing my stamina, which is how I came up with this situation. I didn't notice this situation initially. Let's see, who's that? 45 Xray? No, that's the one I was holding.

INTERVIEWER: What's going on here now?

CONTROLLER: I realize that I had radar-identified him, but I did not radar-identify him. And I'd initiated traffic in this situation.

INTERVIEWER: Who did you identify?

CONTROLLER: I did radar-identify 2 Hotel-Hotel, but I realized then that I'd forgotten to radar-identify Cactus 45.

INTERVIEWER: Okay. Good.

CONTROLLER: That was that. I didn't issue traffic in this situation, even though I was aware of it.

INTERVIEWER: What was the situation between—was that between—

CONTROLLER: These two. I didn't issue traffic. In fact, I didn't issue the traffic to any of these three. Normally you'd do that.

INTERVIEWER: What else is going on here?

CONTROLLER: I recognized the situation that Delta 269 is a lander at some point. I didn't realize the overtake of the situation, and this guy's really fastly overtaking him.

INTERVIEWER: So you didn't realize it at the time?

CONTROLLER: I didn't realize it at the time, no.

INTERVIEWER: Is the workload getting to you now?

CONTROLLER: Yeah, it's getting to me. You know, I was thinking here oh, Christ, what's the altitudes for approaches, airspace, and what I'm going to talk down. Because I unusually have—approach control quite that low, at least where I am.

9:15 Minute Freeze

INTERVIEWER: Thomas, at 15?

Very good, thank you. Okay, here we're frozen at 9 minutes, 16 seconds into the problem. And if you'd go ahead and project out a minute, sum up key aircraft and key properties there, and then come back in and talk about any kind of major decisions, any kind of plans that might have been going on at this—you know, again from here up to 10—10:16.

CONTROLLER: Is it okay if I just go through the list here?

INTERVIEWER: Yes, go ahead.

CONTROLLER: Okay. Brash 55 I knew was landing at McAlester, so I at least wanted to get him started down. I'm most aware of this situation here where I'd initiated the traffic, and—

INTERVIEWER: That's what, Hotel-Hotel?

CONTROLLER: Yeah, and they were tied down and I needed to get him up. I just hadn't got around to doing that. I was concerned about the altitude of approach, and I had to think about that for a minute. And I also recognized about that time that I needed to do something with Air Evac, but this caught my attention over here, the fact that 1 Bravo Golf and 25 Xray were nose to nose. And at the same time I'm still thinking about these two, what I need to do to get them in on Tulsa 1 arrival and formulate the clearance that they needed. Other than that, I wasn't really thinking too much else.

INTERVIEWER: Right. So what point now—was it in the next minute that you went ahead and addressed these?

CONTROLLER: Yeah, I wanted to address this right away I think, almost immediately after this time.

INTERVIEWER: And what did you do or what kind of action or—

CONTROLLER: I just gave him the same clearance to get him underneath the 25 Xray just so they're separated. And after I'd done that, I got another couple of minutes to realize I need to get him down to make sure these guys aren't a problem that needs to get down on Tulsa 1 arrival—American 27 and Delta 269.

INTERVIEWER: Okay. Any other kind of plans or key decisions that you made in the next minute?

CONTROLLER: Well, I made the decision here that even though he was not getting the vector he asked for, he was going to run around the corner of that weather, that I was going to leave him there. The same with this one; he wasn't going to get the service he requested. It wasn't a priority. What I needed to do was separate the people I had.

INTERVIEWER: Right. So the key priorities at this point become the—

CONTROLLER: This separation here.

9:15 - 10:30 Sequence

INTERVIEWER: Right. Good. Okay, we'll go ahead and run it out a little longer here.

Go ahead.

CONTROLLER: I recognize the situation, Bravo Golf's extending towards separation there.

INTERVIEWER: What's going on now?

CONTROLLER: The thing here, I need to do something here. And when he calls me—I heard what he said but I wanted to verify because I was thinking about something else.

INTERVIEWER: Uh-huh.

What's going on now?

CONTROLLER: There's vector separation there between Bravo Golf and 25 Xray. And I'm looking at the handoffs. This is about the time I think I asked for help or mentioned the fact that help would be nice.

10:30 Minute Freeze

INTERVIEWER: On 30?

Okay. We're frozen at 10:31 on the problem, so go ahead and take it out 10:31 to 11:31 on key factors on the planes, and then we'll talk about the decisions, any kind of plans and that stuff.

CONTROLLER: Okay. I'm looking at this, to get them started down to meet the restrictions. I had not noticed the speed differential between Delta 269 and American 27.

INTERVIEWER: Not even at this time?

CONTROLLER: No, I hadn't.

INTERVIEWER: Not on out for the next minute?

CONTROLLER: No, it didn't even dawn on me. I was looking at—my attention was over here, and also the fact that these guys were late getting their climbs. I think it was another minute or two before I even got around to getting them up. In fact, I was making sure we had separation here, and it dawned on me—that's the point I looked—about where I looked for the Air Evac 742 and realized that he was going to the edge of the weather, but he was around the heavy precipitation, so I just said I haven't got time to worry about it.

INTERVIEWER: What else? How about any of the incoming or the—

CONTROLLER: I'm looking at those, and I knew I didn't have time to look. I knew he was a lander and I knew he was a lander.

INTERVIEWER: What, Continental and American there?

CONTROLLER: Yeah. Plus, I look for visual clues. I don't know whether it's entirely around the country, but like at Salt Lake if the guy's landing in San Francisco, I'll have an answer or something in my data block. So I don't have to take my eyes away from the scope to determine whether there's somebody at the space or—I can determine that way. And that was—there was enough going on and I was thinking about all of those things.

INTERVIEWER: Okay. Any specific overall plans or any sort of lower-level decision you had to make here in the next minute from 10:31 to 11:30?

CONTROLLER: No, other than getting this guy started down to make the restriction or at least make it down to the altitude he needed for Tulsa. And I hadn't decided—I knew these two were going to be a problem, and I hadn't had time to look and see where Bandit 8 was. He was at 14 so I wasn't too worried about him. I figured he was an en route guy. And then about two minutes from now I had trouble remembering who the centers were and who to handoff to, and I remember this thing started flashing by itself. I said, good. I didn't realize we had automatic handoff here, so I would have just let everything go.

10:30 - 11:30 Sequence

INTERVIEWER: Okay. Should we go ahead and start back up then?

CONTROLLER: Yeah, start it back up.

INTERVIEWER: Very good.

Okay, go ahead and keep talking about the situation.

CONTROLLER: This is the point where American 21 is getting his descent clearance. I picked an altitude I knew that was safe to get him started down.

There I am, I'm looking at American 33 when I take the handoff and talk to him the first time. Then I bring my attention to him and realize I'll need to space this Continental 56 and American 33. Also, the fact that 25 Xray is en route right through the arrival airspace that I've got, I can't get everybody down. Let's see what else we got?

At that time I realized Cactus 45 and 2 Hotel-Hotel had about got their clearances, so I'm getting them up to a safe altitude reference Brash 55.

11:30 Minute Freeze

INTERVIEWER: Okay. I might move this just a tad.

I think we're pretty good here. I think we should be more or less on time here. Now, go ahead again. Take it out to a minute ahead here. Why don't you go ahead and review the aircraft here in the next minute, significant things happening to them and so on.

CONTROLLER: I'm just looking at this mess here I've got. I've got five airplanes all within at least 10 miles of each other, all Tulsa. So I'm looking at this because I've got to do something when I get these guys. And I'm also planning on having—with this key cage on here that I'm having to fumble every time I put an entry in there, because I normally don't use a slueball for my entries. I do everything with a keyboard. But when you have to—

INTERVIEWER: Get right in the center of it—

CONTROLLER: Yeah, you have to look and peek and poke, and it takes a while.

So—what was I going to say?

INTERVIEWER: In terms of just also as you talk about this, indicate—I think it was actually just a tad before this that you indicated it would be a good time to ask for help.

CONTROLLER: Yeah, when I saw this bunch here.

INTERVIEWER: Okay. So it was really just that large group that really pretty well indicated that that was time. Were there any other indications that this was a good time to ask for help? Had it built up to that point or—

CONTROLLER: Well, the fact that I had let the strips go completely. I wasn't paying any attention to those. That was an indication, and that was a good indication. When you start letting the strips go, then your attention is here and you can't afford to have it split. If that's the case, you should just have a D-side. And if it gets—as far as I'm concerned, when it's a radar problem and I can't clear up that, then I want a handoff or a tracker—another set of eyes. When I start to lose the picture on this—

INTERVIEWER: Now, did you get to—you got to the point of needing a D-side about what point? That was before here?

CONTROLLER: It was before here, but it was more or less because I'm not that familiar with the area. I looked it up and said, well, it wouldn't have made any difference if I'd looked at the damned things or not, there's no use in scanning that and getting the information that you need to derive off that. You can do it immediately. You know, when you're familiar with the area you're familiar with the routes and so forth.

INTERVIEWER: Okay. And in terms of—at what point was this getting to the point where you actually might need another pair of eyes or a tracker, or is that a little further on? Or did you ever really get to that point?

CONTROLLER: I don't think I ever really got to that point. I mean, I may have—I don't recall that I had these separations. Maybe I did, but at least I had control of the airplanes. I mean, nobody was pointed at one another. I don't think they were anyway.

INTERVIEWER: Yes. Okay, here in this next minute are there plans or major decisions that were going on here? Because you've got a lot of stuff going on here, so I assume that you—

CONTROLLER: Yeah, I was thinking I've got to wait until these guys cross into my airspace and then I can jerk the speed back and do what I have to do with these five that are arriving. And I'm also thinking that I can't afford to disregard the rest of the aircraft either. I'm thinking about 25 Xray, the fact that he's en route to the middle of this mess. About this time I noticed this guy is squeezed up a little bit but really hasn't hit the speed differential quite yet. I didn't really realize it until here, the fact that these guys need to get up higher. About here is about where I started messing around with trying to get the handoff, and I can't remember whether it was Kansas City or Memphis, or who the heck it was. That was about—it doesn't seem like too much now, but it seemed like an awful lot then.

11:30 - 14:00 Sequence

INTERVIEWER: Yeah. Okay. Well, let's go ahead and start this back up again.

Thomas? Okay, what's going on now?

CONTROLLER: All right. This is where I'm thinking what I ought to do. I'm thinking it's not my airspace, I've got to wait until they cross this boundary before I do anything.

The other thing was just at least there would been time to look. I looked at Bandit to see if he was an en route or something that I needed to worry about as far as where they were on the airway and so forth.

I'm developing my plan here and deciding who's going to go first. I decided that these two will be before these two, or actually picking my sequence, one, two, and three. And I'd meant to get back and reduce this guy, United 89, to 250 knots as soon as he crossed my boundary. I didn't get to it until about here so I ended up spreading them for the separation so I'd have the five mile in-trail or whatever. Because I knew I was going to pull these guys down. And then I'm worried about getting the altitudes to make sure they all clear 25 Xray on their descents.

INTERVIEWER: What else is going on here? So you pretty well—

CONTROLLER: Yeah, my focus was there. That's why I missed this overtake here. Also, thinking that I have Bravo Golf, whether he goes in the hole or makes the approach. I've got Brash coming down. These guys have got to go over the top, and underneath this one—

INTERVIEWER: Underneath who?

CONTROLLER: The Brash.

INTERVIEWER: Okay. What else is going on now?

CONTROLLER: I'm just scanning to make sure everybody's separated.

INTERVIEWER: Anything have your attention?

CONTROLLER: This did. The fact that the departures—I had to think whether that departure route cleared my arrival route. Then the next—we have another guy. There's the other guy comes off. I wasn't sure who was who here for a second, and I was over here fumbling around with this. This is about the time I handed off, or attempted to handoff Air Evac to whoever this was, Kansas City, and I couldn't remember who it was.

INTERVIEWER: Okay. What else?

CONTROLLER: What else. What else am I doing here? I'm just effecting this sequence, doing what I need to do to keep them separated and get them where I want them to go.

14:00 Minute Freeze

INTERVIEWER: Okay. Thomas?

We're not frozen yet. We didn't freeze.

Okay. We're frozen at 14:12, and I think that's probably about right on the tape, hopefully. Why don't you—

CONTROLLER: My current focus was here—

INTERVIEWER: Okay. Why don't you go through with the aircraft and all that. Again, from here take it out a minute so you not only indicate what's here but what's going to be happening here in the next 60 seconds.

CONTROLLER: Okay. American 33 was numero uno. So he'd go in and I wouldn't reduce the speed until I got him right to the gate. Delta 12 is going to go in next. It looks like a pretty good run there, based on the speed. I'd reduced him and I'd reduced him. These two look like they may be a problem. That was the one I decided if he got a little closer I'd just pull him out and spin him back in this way. These two I'm pulling down this way because I decided those before—

INTERVIEWER: So that's Southwest 56?

CONTROLLER: Yes. Because I realized now he's probably gotten pretty close to the boundary. One of my biggest jobs at that point is making the arrival sequence for those five airplanes. And that's about the time I was having trouble with this—

INTERVIEWER: With whom?

CONTROLLER: With Air Evac 442, trying to get the handoff effected. The other thing was I looked over here. All of a sudden I saw all these—all this stuff flashing at me. I thought what the hell have I gotten here? And trying to get the keys going again—

INTERVIEWER: This is all out of Tulsa here?

CONTROLLER: Yeah, coming out of Tulsa. I realized I needed to get Cactus 45 up and I don't remember if I climbed him up to 25,000 or something else. But rather than the 23,000 I should have put my low-altitude stratum. In any case, I had that going on. And let's see, what else did I have going on? Everything else was kind of on hold.

INTERVIEWER: How about the overtake down here? Was that something?

CONTROLLER: Oh, I still hadn't recognized that I think until they got up to about here, while that was something I should have seen right away.

And these two, United 89 and 25 Xray, were no problem. I mean, as soon as I could get him started down I'd get him started down to effect the vertical separation there. I wasn't worried about this one or the Southwest 56.

And back again, I was trying to remember what facility this was, whether this was Memphis or Kansas City right up on this line. And then it dawned on me when I saw the automatic handoff effected and I said, oh, okay. I don't have to worry about that anymore.

INTERVIEWER: Okay. Now, how about any sort of additional planning for what's coming up ahead here for the next minute, or any major decisions in the minute?

CONTROLLER: Well, I had picked my sequence. I was just going to do whatever I had to make it work. Whatever else it was, I'd just make it work.

These two I was watching, but it hadn't dawned on me quite what the overtake was because they still look pretty good. And then at some point—I don't remember whether I did anything. Did I ever do anything with these two?

INTERVIEWER: Yeah, we'll have to see when we get down. Yeah. Okay, anything else?

CONTROLLER: No, everything else is pretty much separated, so I wasn't too worried about it. I was just trying to get this done and then sort out my departures here and get everybody climbing that I needed to get climbing.

INTERVIEWER: How about workload at this point? Any thoughts there?

CONTROLLER: Given the familiarity with the sector and so forth, the procedures, I was at my limit. But normally, I think it was something somebody could handle. But when you have to start thinking about everything you do rather than it being automatic—and even just effecting this, I have to keep thinking what is my altitude for Tulsa arrival? Is it 11,000 or 12,000, whatever it was, and the speed restrictions, and so forth.

14:00 - 17:00 Sequence

INTERVIEWER: Okay. Let's take it on out to the next freeze point.

Okay. Go ahead and talk it through here.

CONTROLLER: Okay. I'm looking at this and I'm saying, Delta 711, great, just what I need—another arrival.

Here I am, Delta 12. I'm getting him down so I can get this one, United 89, underneath the 25 Xray. So I'm getting the latter down. I'm still trying to just take care of what was going on in the rest of the sector.

I can see the handoff but I still couldn't sort him out from all my other data blocks. So I'm taking Cactus 45 and I'm climbing him up to—I knew 22 was an altitude I was okay and he was going to make the climb here reference 377.

That one's arrival over here. I received this one and I'm going to need to get him climbing here shortly, 2 Hotel-Hotel.

That was a mistake because that's not my altitude. And I never did talk to—I was thinking why haven't I talked to United 41? I've talked to the Southwest who's only out of 86 down here. But here's United 41. In fact, I had call him to tell him to start up.

INTERVIEWER: Now what's going on?

CONTROLLER: This is about the time I became conscious of the situation of the overtake here. I knew I had vertical and I wasn't too worried about it yet.

INTERVIEWER: Okay, when you hit that—

CONTROLLER: And I saw that I had the vertical, effected the handoff of Cactus 45 to Sector 2. This is about the time I noticed—why doesn't that show? I guess it doesn't show even though I had a handoff?

Let me think about that a minute.

I'm standing back and I'm making sure this is—this is about the time I decided that United 89 was not going to fit in the five behind—yeah, there we go—so I pulled him out.

INTERVIEWER: Okay. Now, does the tape sound like it's about right for the scope, or were you running a little—

CONTROLLER: Yeah. That's just about the time I pulled him. Delta 711 was coming up before I realized they were both en routes. I glanced at the strips. And they—you know—

INTERVIEWER: What's happening now?

CONTROLLER: That's where I was messing around with the handoff, and I probably got it.

So we've got one deviation, two deviations—okay. That's when I realized 23 was my altitude.

So I got her started up, and because of this I don't think I picked up right away on the screen. Right there—there we go.

17:00 Minute Freeze

INTERVIEWER: Okay. Great. We're frozen here at 17:01. You know, take a good detailed look here and go through the groupings of aircraft. And remember to take it out for another minute or so in terms of a description of what's going on and what will happen in the next minute.

CONTROLLER: Okay. Air Evac 742 is no longer a factor. I finally got the handoff done or it automatically did it, I think. This one, I was deciding whether it was Memphis or Kansas City. In fact probably needed a point-out there, but I didn't do it. It wasn't one of the things that was a priority at the time. Delta 711, I'm kind of alert—84, I had realized were in route, I wasn't too worried about. I had already started everything I needed to do with my five aircraft that were arriving for Tulsa and had effected the separation and the sequencing I wanted.

INTERVIEWER: And what was that? That was all—

CONTROLLER: American 33 was number one. Delta 12, I spun in once to get him back in trail and separated him from 25 Xray. He was going in. And, in fact, if I had gotten around to it, I would get these turned back in a little quicker. But I didn't get around to it. Because these two were the next—Continental 56 and Southwest 56 were four and five; no problem. Down here, Delta 269, I realized the overtake. Reduced him to 250. And American 127, I stared his descent to 11 to meet the Tulsa requirement. Bravo-Golf was still in the hold and I wasn't too concerned about him. I did realize that Brash 55 needed to get either down underneath him or get him started on his approach. And since he wanted to practice hold, as far as I'm concerned Brash 55 grabbed the approach first. En route, 22 Yankee is a problem for Brash 55. Could make it an unrestricted approach. I knew that, but it wasn't a priority right at that time. 2 Fox Mike was en route. I wasn't too worried about him. Cactus 45, I'd effected the handoff; got rid of him. Figured out who I had off what frequency and so forth. Lear 2 Hotel was handed off and going to high; I wasn't too worried about him. 377 was an en router. I'm talking—this was about the time I think United 41—I either called him and talked to him to make sure I had him because he never checked on. Or maybe that was a second or two before that.

I've got Southwest climbing to 26, which is not my altitude, which is not good. 25 Xray is en route. I didn't see the VFR traffic and never issued it. And that's about it.

INTERVIEWER: Okay. Any plans at this point or any key decisions coming up in the next minute?

CONTROLLER: Other than to finalize my—this is about the point where I know United 89's turning back in. I'll turn Continental 56. Southwest 56 will go down right behind him on the turn. And I'm watching these two because if that doesn't work with the speed—if he doesn't get back where it's working, then I'll have to pull him out and sequence him, some kind of spacing.

INTERVIEWER: Okay. Let's run this through to 20.

17:00 - 20:00 Sequence

CONTROLLER: Two deviations.

INTERVIEWER: Go ahead. What's going on now?

CONTROLLER: Just effecting the scan. I think I was going to get—concentrating, realized suddenly else. It dawns on me the Delta 269's already—you do something and even though you've effected some kind of action and they're separated, it still draws your attention and you've got to get back and look around.

He's going to high. He's no longer a factor as far as I'm concerned.

Continental 56 should be my next move, to bring him back in. American 27 is going 11. I think it's what I gave him. Yeah, I gave him 11—got him on the data block, American 27. And this is starting to look okay. These are starting to work, these speed reductions.

That should be my next move. I don't have anything else going. Other than I don't think I talked to—there he goes, he goes for the turn. I was looking to take the handoff on this one and I realized I have no traffic for him virtually unless he turns to the south.

Going down to make the restriction to Tulsa, Delta 12. This one needed a point-out—I think that's where the airspace—but no, it's not. That's the airway. Okay. He was okay.

I dropped the data block here, he's out of my airspace and climbing.

I realize I've got to give him the speed before I shut him over, even though he's technically in the airspace.

He turned back in. So as far as I'm concerned, other than the altitude restrictions I've met the requirement for all my in-trail spacing. So that's not really a factor other than monitoring at this point.

Unfortunately, I never saw this. Did you?

INTERVIEWER: Huh-uh. That was—

CONTROLLER: We quit before it became a problem. But that would have been a problem.

INTERVIEWER: Yeah.

What else is going on here?

CONTROLLER: Did I spin him? Yeah, I spun him once. I remember doing that. I gave him a turn to get him back in. I should be doing Brash 55, getting him down to get him underneath this one, but I'm still working—still on this side.

INTERVIEWER: You're working this side? Yeah.

CONTROLLER: Yes. In fact, I should have had him started down a lot sooner than that.

25, I make sure there's not a factor en route. He's just separated from everybody else so I wasn't really thinking about him.

INTERVIEWER: Okay. What else?

CONTROLLER: Other than—I didn't even see that.

There he goes, okay.

INTERVIEWER: That's United 41?

CONTROLLER: Yeah. I realized he'd never started his climb.

And then while I'm handing this one off, I'm back here playing with trying to get that damned Tulsa in there. I forgot what the ID was.

INTERVIEWER: Oh, yeah. West T-U-L?

CONTROLLER: Yeah. T-U-L. And that was about it. We quit at about that time.

INTERVIEWER: Yeah. I think we're frozen at 19:59. Very good. Okay. Let's just leave it there. Reviewing it now, did you notice anything different that you were doing, say, as the traffic level built? Any different sorts of strategies or things that you were doing a little differently? Any reduction, any sort of workload reduction sorts of things that you might have implemented? Not only that you did implement or that you now maybe seeing a second time you think you might implement? Go ahead and make the thing as manageable as possible given the situation.

Again, we're kind of looking for things that you, based on your experience, might have done to reduce the workload level a little bit so that you could go ahead and concentrate on the key things here.

CONTROLLER: Not so much with this. In the real world I would do things. If I anticipate weather and so forth, then I want to take whatever steps are necessary so I don't get saturated. Say if I normally go—if they've got to clean the runways in 30 minutes, they've got to restore it a little, I'm not going to allow every aircraft in the center in my airspace. I would have done something or I would have established a holding sequence and at least anticipated what I'm going to do. If I know I've got weather coming up at the gate, I would eliminate vectors—people that I had on vectors for navigation and so forth—put them back on their own navigation. I'd have called for a D-side. I would reduce my paperwork so my attention was here. This normally wouldn't be any problem for a radar controller familiar with the area because it's manageable. It really is. I can see a couple of things I would have done a lot differently.

INTERVIEWER: What kinds of things would you have done differently?

CONTROLLER: I would have set that spacing up a little quicker. Other than that one, well, the only thing really different is that I had to think about everything I was doing.

INTERVIEWER: Right, because of the sector unfamiliarity and—

CONTROLLER: Yeah, and normally you wouldn't—everything is second nature. You know, you do it often enough that it's second nature.

INTERVIEWER: Well, what were the key things that really made a difference in the fact that this was not your normal sector? What were the major ones? Was it just sort of knowing the adjoining sectors and knowing the various requirements for the airports and all?

CONTROLLER: It's—yeah. Their not being second nature, not having confidence in the knowledge you do have. It's one thing to know generally what it is. It's another thing to do it and have the confidence that it's done right the first time. Because everything I had to—well, is that right? Even though I probably thought about it and had seen it and said, well, that's okay. But like the guy vectoring the VFR there that popped up, even though 12,200 I knew was a good altitude, I just instinctively could not do it. I couldn't bring myself to turn that guy.

INTERVIEWER: Now, one of the things you mentioned was in terms of when you saw a bunch of arrivals coming in over here is when you sort of started realizing that you'd want some help. Were there any other indicators? Anything sort of leading up to that? You know, we've had a whole range of people looking and saying, well, if I see all these many strips in this time-frame, I ought to ask for a decide right away type of thing, all the way up to other kinds of indicators. Was anything else—

CONTROLLER: The number of strips don't bother me because they're really not a factor. I mean, you say, well, okay, you get a lot of strips, you'll probably get some traffic. Well, not necessarily. You might not get them in the time sequence that affects you. To me it's when I cannot—I don't have time to keep up with those strips and keep them current. You know, not how many strips I've got but if I can't keep the ones that I do have current, then it's time to get some help so I could take my attention from there to here.

INTERVIEWER: Okay. Any other kinds of indicators?

CONTROLLER: No. Just the fact that I had weather, there was weather in that sector. And the fact the number of arrivals I had indicated that each—based on the times that I was going to be required to focus on that. And once you start focusing on one area, you tend to lose the focus on the other area. So you're not keeping your scan up and other things.

INTERVIEWER: If you hadn't had, say, the workload level and there were either fewer arrivals, or whatever, would you handle the arrival situation significantly differently, or would it—in other words, did you try to optimize or reduce the amount of actual coordination and handling you had to do in this case just based on the fact that you did have an increased workload? How did you handle that, or what did you end up doing differently? Or did you pretty much just kind of formulate the plan as you would independent of the workload level?

CONTROLLER: It would be independent of the workload level, based on what's going on. I mean, you can go down the tubes and get actually so far behind with one or two VFR's that are tying your frequencies up or something than you can be with any number of IFR aircraft. All it takes is one yoyo tying you up, and all of a sudden a sector that should be normal and routine all of a sudden just goes to pieces.

INTERVIEWER: Good. Well, one last thing just in general about the problem. Was it pretty realistic and so on?

CONTROLLER: Oh, yeah. Yeah. It was a good problem. It wouldn't have been any problem if I was more intimately familiar with the area.

INTERVIEWER: That was sort of the main thing for you. Even more so than not having a decide, was just the unfamiliarity with the sector?

CONTROLLER: Even at that, though, my strip marking would have gone by the side. There's no way I could have kept up with the headings and all the stuff I was doing, because all that stuff has to be in your head other than to be on paper.

INTERVIEWER: Great. Okay. Good. We're done. Thank you much.

(End of Tape B08 interview.)

APPENDIX E: WORK OVERLOAD QUESTIONNAIRE

Controller Work Overload Questionnaire

Date________________ Time_______ Experimenter________________ Controller No.__________

You have just completed a problem that was designed as a work overload situation. The problem was constructed in order to help determine how controllers make decisions when they are in an overload situation and to determine the early warning signs of work overload. We hope to develop a table of early warning signs to help novice controllers recognize when a critical situation is developing and when they should ask for help.

Please answer the following questions as completely as possible by providing all details. These data are being gathered anonymously and the answers are confidential. Most of the questions deal with the problem that you have just solved, and if you need any more information, please do not hesitate to ask.

1) On a scale from 1 to 7 (1 being a very light workload and 7 the heaviest possible workload) please rate the following (divide the problem into four quarters with each lasting about 5 minutes):

First quarter of the problem: ______

Second quarter of the problem: ______

Third quarter of the problem: ______

Final quarter of the problem: ______

Overall (entire 20 minutes): ______

2) Did you ask for help, and if so, what type of help?

3) How did you know when to ask for help?

4) If you did not ask for help, how did you know it was not required?

5) How did you know what type of help to ask for?

6) The following is a list of indicators or cues that have been identified as warning signs of controller work overload. Please indicate if you felt any of these by numbering them in the order you experienced them.

Feeling Anxious or Nervous: ______
"Tunnel Vision": ______
Conflict Alerts: ______
Unsteady Voice: ______
Failure To Hear Pilot Requests: ______
Decreased Self-Confidence: ______
Computer-Entry Errors: ______
Aircraft Overtakes: ______
Sweaty Palms: ______
Feeling of "Deja-Vu": ______
Handoffs Not Executed: ______
Pointouts Not Given: ______
Other (Please specify): ______________________________
Other (Please specify): ______________________________
Other (Please specify): ______________________________
Other (Please specify): ______________________________

7) Please specify the relationship between key work overload warning signs you experienced and the strategies or actions you took by completing the following:

Warning Sign	Strategy or Action Taken

8) If this had been a real situation, would you have experienced some other signs of work overload? If yes, what might they have been?

9) Please rank these warning signs from 1 to 12 in terms of their importance. Based on your experience, which warning signs are the most important indicators of work overload (1 is the most important warning sign and 12 is the least important):

Feeling Anxious or Nervous: ______
"Tunnel Vision": ______
Conflict Alerts: ______
Unsteady Voice: ______
Failure To Hear Pilot Requests: ______
Decreased Self-Confidence: ______
Computer-Entry Errors: ______
Aircraft Overtakes: ______
Sweaty Palms: ______
Feeling of "Deja-Vu": ______
Handoffs Not Executed: ______
Pointouts Not Given: ______
Other (Please specify): ________________________________
Other (Please specify): ________________________________
Other (Please specify): ________________________________
Other (Please specify): ________________________________

10) What strategies did you use and what actions did you take to deal with the overload situation, and how did they reduce the workload?

11) In your experience as a controller (without reference to the DYSIM problem just completed), what are the warning signs of work overload, and what strategies do you use to deal with the control overload situation?

Thank you for your help.

APPENDIX F: ERROR LISTING FOR DYSIM OVERLOAD PROBLEM SOLVING

B01 PERFE

0:00 to 7:30 SEGMENT

5:30 257X is a primary target, controller turned for ID and never turned back.

7:25 Controller did not establish vertical separation between 28HH and AWE45.

7:30 FREEZE POINT

Everything is being done routinely.

He is talking faster starting at about 5:00 and sounded frustrated.

Working 257X may have gotten controller behind.

7:30 to 9:15 SEGMENT

8:10 Descends 31BG to 21,000 for traffic while still in Memphis airspace.

9:07 Reduced speed on DAL269 to 250 and descended to 13,000 while still in Fort Worth airspace.

9:15 FREEZE POINT

Could have facilitated by giving DAL269 and AAL27 PAR (Preferential Arrival Route) when they first called up.

Controller is trying to do things in a hurry, so these are clear indicators that controller is busy.

9:15 to 10:30 SEGMENT

9:47 Controller says, "1BG say again." (Indication of heavier workload.)

10:27 Controller says, "Brash 55, say heading." (Possible indication of heavier workload, since he has just given it to him.)

10:30 FREEZE POINT

10:30 to 11:30 SEGMENT

10:55 Slowed and descended AAL33 while still in Memphis airspace.

11:18 Controller calls for help.

11:30 FREEZE POINT

Controller is doing things out of habit, rather than planning. He is reactionary.

11:30 to 14:00 SEGMENT

11:44 Controller attempts to spin DAL12 unnecessarily (while still at high altitude).

11:53 Controller says, "I give up."

11:56 Controller reduces UAL89 to 250 while inside Memphis airspace.

12:40 Descends DAL269 and AAL27 below 18,000 without giving altimeter settings.

13:05 Gives Brash 55 a vector without giving a reason.

13:19 Inquires "UAL41 to what altitude?" (Distracted)

13:25 Instructs UAL41 "stand by for higher." (Distracted)

13:30 Controller should have issued traffic to UAL41.

14:00 FREEZE POINT

Controller still does not have a plan for the arrivals.

He is still concentrating on his strips at this point, which may be a mistake.

14:00 to 17:00 SEGMENT

15:00 Vectors DAL12 and slows him down while inside Memphis airspace.

15:20 Inquires SWA44 "Who was that calling?" (Distracted)

15:55 Clears COA56 direct to TULSA VOR (violates letter of agreement) and hands him to TUL and changes his frequency with no coordination.

16:50 Controller asks DAL12 for heading.

Controller slowed DAL711 for arrival when he was an overflight.

END OF LISTING

B05 PERFE

0:00 to 7:30 SEGMENT

1:10 Scenario frozen accidentally.

3:50 Controller gives 257X, a VFR pop up, IFR clearance without radar identification (no data block) (cleared to PNC at 12,000).

4:55 Controller answers the call from MIO before finishing taking care of 257X. (Poor priorities)

5:20 Clears AWE45 off of MIO to 9,000 without knowing where 257X is.

6:30 Controller is behind on his handoffs. (Indication of heavier workload)

7:23 Controller says, "I would get help at this point, because I am not familiar with this facility."

7:30 FREEZE POINT

Controller needs to speed up.

Controller starts reacting and is behind after 7:00 minutes

7:30 to 9:15 SEGMENT

7:34 Controller would ask for a D-Side, based on the configuration of this lab, might ask for a tracker instead.

8:25 Clears HH to 8,000 (has no vertical separation with AWE45 and 257X).

9:15 FREEZE POINT

Could have given AAL27 and DAL269 PAR's on initial call.

Failed to see AWE45 when he first came up on the approach airspace.

9:15 to 10:30 SEGMENT

9:20 Gives 1BG the wrong heading for ILS approach and violates Memphis airspace.

10:30 FREEZE POINT

He vectors 1BG for a straight in ILS approach, rather than VOR approach (which requires less workload).

10:30 to 11:30 SEGMENT

10:45 Controller allows AWE45 inside TULSA airspace with late pointout.

11:20 Controller allows 1BG to enter Memphis airspace without pointout.

11:30 FREEZE POINT

Missed two pointouts, a clear sign he is behind.

He has abandoned his strips at this point, and that is helping him.

11:30 to 14:00 SEGMENT

12:07 Controller says, "I cannot keep up."

13:20 HH gets into TULSA airspace without pointout.

14:00 FREEZE POINT

Controller does not issue clearance on 68412.

14:00 to 17:00 SEGMENT

16:30 Controller does not give SWA44 a climb above 10,000.

16:58 Controller says, "We can continue this, but it is completely out of control."

17:00 FREEZE POINT

The five Tulsa arrivals are not sequenced, and separation is doubtful.

Both AAL and DAL are within 20 miles of the fix at 24,000 (they have been forgotten) and neither have been cleared on the PAR (pilots should have been cleared to the TULSA1).

Controller fails to see the overtake on COA84.

Controller lets 425X go by P57 (Prohibited area).

END OF LISTING

B06 PERFE

0:00 to 7:30 SEGMENT

1:00 Controller does not climb 68412 (keeps him at 10,000). (He does climb him to 13,000 at 6:32.)

6:11 Controller vectors AWE45 on initial contact without radar identification.

6:50 Holds 282HH until 15:00, when he will be very busy.

7:27 When AAL27 calls, controller asks, "Who called?"

7:30 FREEZE POINT

The fact that he has an inquiry about the AAL27 call indicates that the workload is increasing.

7:30 to 9:15 SEGMENT

8:20 Controller descends 425X rather than BG. BG is the MLC lander.

9:01 Climbs AWE45 to 16,000 but there is VFR superimposed with his block, and he should have issued traffic.

9:10 Controller vectors N31BG for the straight in ILS (poor choice from workload view).

9:15 FREEZE POINT

9:15 to 10:30 SEGMENT

10:29 Controller asks, "Who wants to hold at MLC?"

10:30 FREEZE POINT

He should have known what to do with AWE45 before he vectored him (also, he should not have given him an interim clearance).

10:30 to 11:30 SEGMENT

11:27 Controller asks, "Who is flashing where?"

11:30 FREEZE POINT

Controller is not listening to the frequency.

11:30 to 14:00 SEGMENT

12:12 Controller says, "I need help."

12:20 Controller says, "Last aircraft (DAL12) say again."

12:25 Controller reduces and turns DAL12 while still at FL 24,000 (could have done it legally by including "Leaving FL 23,000. . ." in his command).

13:15 Controller reduces and turns SWA44 while still at FL 24,000.

14:00 FREEZE POINT

Controller was late on descending 1BG.

Controller was late in vectoring DAL269 to the TULSA1.

14:00 to 17:00 SEGMENT

14:16 Controller says, "This is getting too ridiculous."

17:00 FREEZE POINT

Controller was late at starting AAL27 down.

Controller did not notice the overtake with DAL269.

Controller gave DAL269 the wrong arrival.

END OF LISTING

B07 PERFE

0:00 to 7:30 SEGMENT

6:30 Controller does not radar identify AWE45 (he did not verbalize that to the pilot).

7:30 FREEZE POINT

He did not give AAL the PAR.

Controller prioritizes well by interrupting and delaying the 257X (VFR pop up) to take handoff on AAL. He left the VFR pop up to answer the line (MIO) and then he did a scan after that before going back to 257X.

7:30 to 9:15 SEGMENT

8:17 Controller says, "Now I would be asking for help."

9:15 FREEZE POINT

Increases speed on AAL27 to expedite the situation at 9:00.

9:15 to 10:30 SEGMENT

9:50 Gives 1BG "Unable holding clearance." (Helps reduce workload.)

10:30 FREEZE POINT

282HH is still on the ground waiting for clearance at MIO. The controller gave him a full route clearance, and then a hold for release which is a very effective time-management strategy since all he has to do is give him a "release clearance." The error is that the controller has not gone back to clear him.

10:30 to 11:30 SEGMENT

11:29 Getting busy now.

11:30 FREEZE POINT

Controller gave 1BG "cleared for approach (VOR)," which may not service the aircraft, but is a good workload strategy.

11:30 to 14:00 SEGMENT

12:24 Gave AAL22 (number 1) a shortcut providing the shortest route.

13:57 Controller did not give UAL41 higher (controller thought he was requesting departure).

14:00 FREEZE POINT

Around 12:00, controller let the strips go. That is good from a workload management perspective.

14:00 to 17:00 SEGMENT

15:00 He is sequencing his arrivals.

16:18 He does not answer the phone (a good way to manage workload).

16:20 Controller violates R1 airspace.

17:00 FREEZE POINT

Controller shortcuts AAL33 and left at speed (1st), DAL12 second (speed control 280), UAL89 3rd slowed to 250, COA56 4th (vector to the left, behind UAL89 on the FORTS1), SWA56 vectored behind COA56.

Controller has not given PAR to AAL27 and DAL269, but they have been descended (may be due to sector unfamiliarity).

END OF LISTING

B08 PERFE

0:00 to 7:30 SEGMENT

4:40 Cleared AWE45 to 22,000 with (68412) head-on traffic 25 miles out at 13,000.

6:39 Controller cleared HH to 12,000 (no separation with AWE45).

7:30 FREEZE POINT

Controller made error with radar identification.

7:30 to 9:15 SEGMENT

7:25 Controller did not clear 257X around WX as per request (this has helped controller manage workload).

8:45 While COA269 was in Dallas airspace, controller told him to "Fly present heading" which could change his route. He should have cleared him on J105.

9:15 FREEZE POINT

At this point, controller is being reactionary, rather than proactive.

Controller did not radar identify AWE45.
Controller failed to issue traffic.

9:15 to 10:30 SEGMENT

10:30 FREEZE POINT

Controller fails to notice the overtake on DAL269.

11:15 Controller says, "Now would be a good time to have some help."

11:30 FREEZE POINT

14:00 FREEZE POINT

He is descending and slowing the Tulsa arrivals right on the boundary, and that is getting him extra time.

He has a good scan going, and is not missing handoffs.

14:00 to 17:00 SEGMENT

14:40 Calls "AWE45, Aero Center" and waits for pilot to respond, rather than going ahead and just giving the clearance.

16:00 Controller spins UAL89 360. With the 360 degree turn, he will be getting 15 miles separation with DAL12 and will be stringing out his arrivals too much. He should have vectored UAL89 (S turned instead). It is not a a very efficient controller action.

17:00 FREEZE POINT

He has let DAL269 run up close to AAL27.

Controller failed to make a pointout.